DISCOVERY

Monthly Notebook

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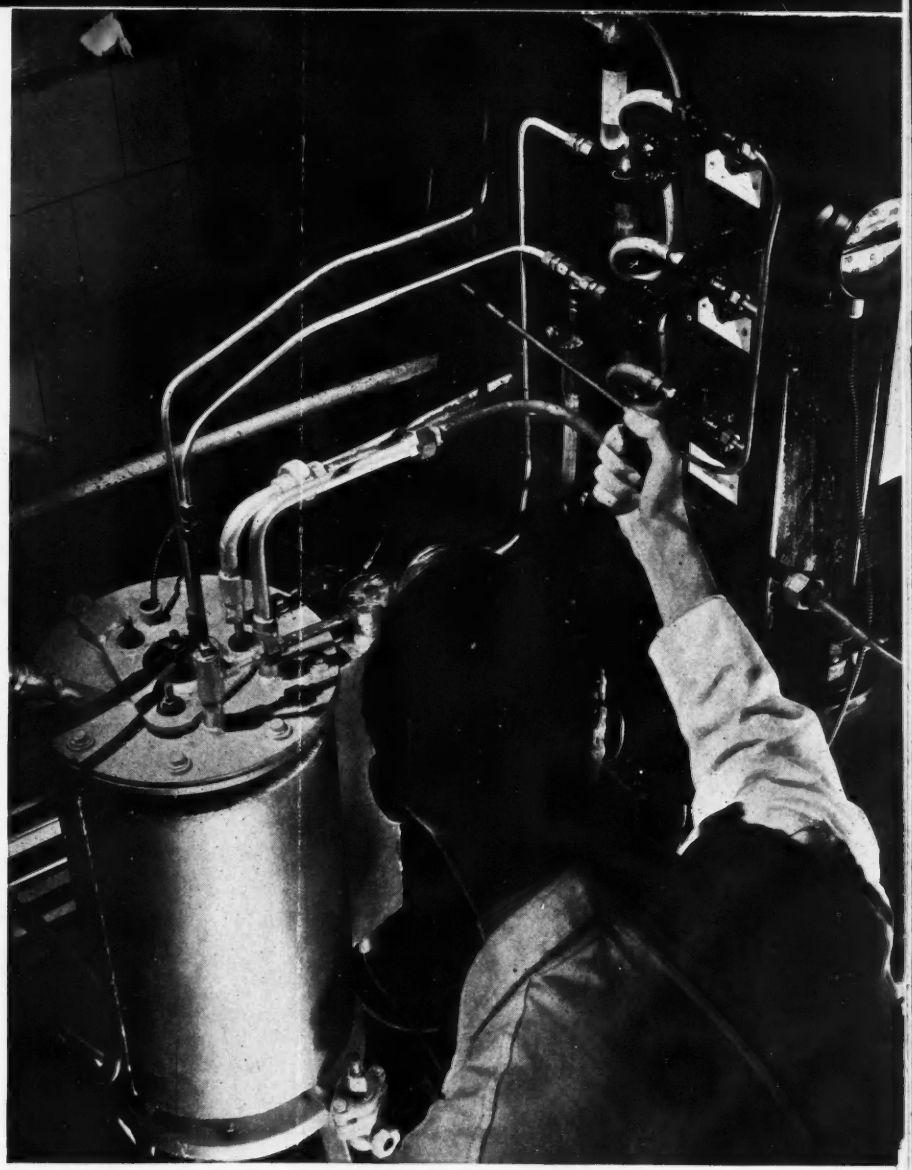
Far and Near



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THE MAGAZINE OF SCIENTIFIC PROGRESS

September, 1950 Vol. XI. No. 9

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The Progress of Science

New Sources of Power

THE most newsworthy of individual contributions to the Fourth World Power Conference (held in London, July 10–15) were naturally those dealing with new sources of energy, or those only lately exploited. One was a proposal for a unique hydro-electric project; water from the Mediterranean would be admitted to the Qattara depression in the Northern Libyan Desert (which is about 70 kilometres from the coast), the flow of incoming water being balanced by evaporation from the salt lake which would be formed. This was first suggested by the late Dr. John Ball in 1933, but is again under study at the present time. The scheme as now proposed provides for a drop of 50 metres below sea level; the area of the lake which would eventually be formed being some 13,500 square kilometres. The cost is estimated at £110 million. Power output would be 300,000 kilowatts, and "it is conceivable that with the creation of a vast salt lake, with fishery prospects, and the possibility of cultivation of thousands of acres around this lake, by means of electric power for lift irrigation from Nile water, a new and vast area could be added to the cultivable area of Egypt."

There was also a session on "Other Sources of Energy" which brought news of some further projects, existing or under development. In his general summary to this section, Mr. C. W. Marshall, Deputy Chief Engineer for Research of the British Electricity Authority, described as "an epic achievement in engineering history" the obtaining of power from volcanic sources in the Larderello district of Tuscany, which "now constitutes an important contribution to Italian industry." The deepest bores have extended to a depth of 3 kilometres, and in a contribution by Dr. Enea Virgili there were "'clear warnings' both of the possibility of wasted bores in an apparently favourable location", and "of sudden violent emissions of steam which endanger the personnel engaged in boring". Mr. Marshall considered, nonetheless, that the achievement was "scientifically and technically of world importance".

A French scheme for the utilisation of temperature differences between tropical sea water in surface layers and at a depth is at the development stage, and was described by Mr. Marshall as being also "of great technical and economic interest". This represents the translation of pioneer efforts by M. Claude into a development project at Abidjan on the Ivory Coast. The immediate proposal is for a land generating station, with a boiler heated by water at a temperature of 82° F., a turbine supplied with steam at correspondingly reduced pressure, and the steam from the turbine exhausting into a condenser cooler by water at 46° F. The installation of an inlet duct, capable of extracting 2825 cubic ft. of water per second has already been fully rehearsed off Brest. The intention is that there should be two generating sets, each of 3500 kilowatt capacity.

The Conference concluded with a session on atomic energy. Apart from an international exchange, involving the Russian delegate Prof. Golubtsov, which was more than adequately reported at the time in the daily press (e.g. *The Times*, 15.7.50), the chief interest was on the question of whether heat could be extracted from a nuclear reactor by a material which could itself be used as the working medium for the driving, for example, of a turbine, or whether an intermediate 'heat exchange' cycle would have to be interposed. There seemed to be general agreement that in the early stages at least a primary heat-transfer cycle would have to be accepted, if for no other reason than that the complete power plant would otherwise be within the intensely radioactive area and surrounded by protective casing, with obvious difficulties in relation to maintenance and accessibility.

There was some cautious thinking on the subject of the cost of atomic power. References to cost are perhaps best interpreted as providing further support for the view that without 'breeding' reactors, producing more secondary 'nuclear fuel' than they consume of primary fuel, prospects of economic exploitation would remain uncertain. They would in any case be necessary if any significant contribution to world power were to be made by nuclear energy.

Sir John Cockcroft, Director of the Harwell Atomic Energy Research Establishment, gave some 'round figure' calculations on the supposition that the breeding reactor had not yet been achieved. Assuming a 30-years' working life, and a capital cost with interest of £12,500,000, he arrived at an obviously tentative estimate of 0·25*d.* per unit, as at the power station. On the same supposition, the meeting of British power requirements alone would

require "an annual supply of about 600 tons of uranium", which is "an appreciable proportion of available world supplies of high-grade ore."

Sir John Cockcroft drew the conclusion that, on this basis, any large-scale development of nuclear power would depend on "large supplies of low-grade uranium becoming available", together with a method of processing which would keep production costs in the neighbourhood of the assumed level. "Breeding," he pointed out, "would probably be started by the development of 'fast' or 'intermediate' reactors" in which there would be respectively no, or reduced, slowing up of neutrons by the inclusion of moderating materials such as graphite within the reactor. Rapid breeding, with the primary fuel burnt in a year, would involve removing energy at the rate of 100,000 kilowatts from only 36·5 kilograms of nuclear fuel—although in a reactor, built solely to test the possibility of breeding, as has been suggested, there would be no necessary requirement that heat should be extracted at a high enough temperature for the generation of useful power.

Sir John Cockcroft made the further point that 'fast' reactors are characterised by a high flux of fast neutrons, in relation to specific power, with the result that "reactor materials are subjected to an intense neutron bombardment and must be stable under this treatment." In other words, whereas conditions could be made easier in respect of temperature, the requirement of structural stability would be otherwise more difficult.

Mr. W. F. Davidson, of the Consolidated Edison Company of New York, quoted current cost estimates for the four experimental or developmental reactors for which there is American authorisation. They added up to a round total of some 80–95 million dollars. He stated that "under present conditions uranium as a fuel for power plants is much more costly than coal, but at some later date may become somewhat less expensive. As to other operating costs, it seems clear that until there has been extensive experience with nuclear power plants, labour supervision, maintenance and repair are all likely to be higher than for coal- or oil-burning stations." On the question of stability under neutron bombardment and radiation, he stated that "scarcely more than a start has yet been made because adequate testing facilities have not been in existence."

Dr. Ragnar Liljeblad (Swedish National Committee) quoted what he referred to as "the current opinion that nuclear power will never be able to compete with well-situated water power, and will have difficulty in competing with energy from coal or oil as long as there is no considerable increase in the price of these fuels."

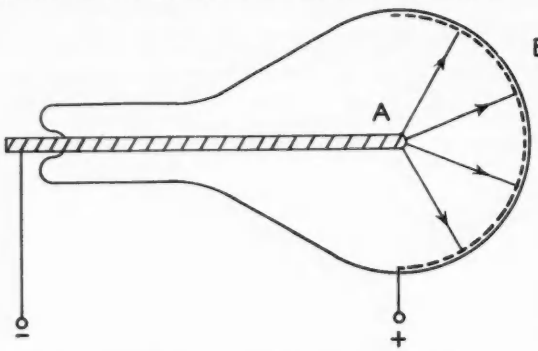


FIG. 1.—Simplified cross-section of a field-emission microscope. The radius of the tip of the tungsten wire A has been grossly exaggerated.

The Field-emission Electron Microscope makes Molecules Visible

IT has recently been reported that Dr. E. W. Müller of the Kaiser-Wilhelm Institute of Physical and Electrical Chemistry, has obtained images of single molecules—actually phthalocyanine molecules—by means of a field-emission microscope he has designed. Since the phthalocyanine molecule is almost fifty times smaller than the smallest molecule so far seen with the standard electron microscope, and since the field-emission microscope is a good deal simpler (one might almost also say cruder) than the standard electron microscope, this news has excited a great deal of interest.

To understand what Müller has done, it is necessary to recall the main features of the field-emission microscope announced by him in 1937. Basically the microscope consists of a tungsten wire with a fine tip *A*, mounted inside a thoroughly clean and evacuated bulb *B* (*see* Fig. 1). With suitable etching techniques, the tip of the tungsten wire can be given a very small radius of curvature. If now, a positive voltage is applied to the surface of the bulb *B*, the field at the surface of *A* can be made very large indeed, large enough in fact to attract electrons out of *A* even when its temperature is lower than that used in thermionic emitting filaments. This is the well-known 'cold emission' (also called 'field emission') of electrons. Since the accelerating field is concentrated in the vicinity of the point *A*, the electrons receive most of their kinetic energy quite close to the emitting tungsten surface and thereafter proceed in straight lines until they reach the bulb *B*. The inner surface of the bulb *B* is covered with a phosphor which glows when electrons impinge on it and in practice, when all goes well, one sees on this bulb a geometric pattern of spots. These arise because while the tungsten tip *A* has a curved surface, it nevertheless usually consists of a single crystal. Certain regions of the surface, related to the crystallographic axes, emit electrons more easily than others and the electrons moving out in nearly straight lines from these parts of the surface, give rise to brighter regions on the bulb.

The magnification of the simple device shown in Fig. 1 would be given by the ratio of the radius of the bulb to the radius of the emitting point. It is not difficult to achieve magnifications of the order of one million times. The image brightnesses are quite adequate for visual and photographic work.

A more important factor however is the fineness of detail which the microscope will show: in other words, its resolving power. The electrons do not in general leave the tungsten point *A* in straight lines directed normally away from its surface. They have a range of lateral velocities. As a consequence all the electrons which left one point on the surface of the tungsten wire at *A* would be spread over a small disk by the time they had reached the screen *B*. This spreading depends on the geometry of the apparatus, the potential difference between *A* and *B* and on the temperature of the tungsten point *A*, but making the calculation for a reasonable case, one might expect that two

points on the surface of *A* would have to be separated by 10 or 20 Angstrom units in order to give discrete patches of illumination on *B*.

Müller has found that if a few phthalocyanine molecules are evaporated on to the tungsten point, then they locally increase the electron emission. A pattern of brighter spots as shown in Fig. 3 is now superimposed upon the original broader pattern due to the tungsten alone. On closer examination these spots are seen to consist of four segments. This is significant since the structure of the phthalocyanine molecule as deduced from chemical and X-ray diffraction evidence looks something like a four-petalled flower, each petal being a benzene ring.

Müller's achievement at once raises some interesting speculations. Shall we be able to look at other complicated molecules whose structure is at present unknown and obtain enough evidence of their shape to shorten the work of calculating their exact structure from X-ray diffraction evidence? Shall we be able to obtain more direct evidence of the way in which large molecules attach themselves to a solid surface and of the way in which molecules migrate upon such surfaces? Müller's work raises the exciting possibility of studying some physical and chemical phenomena visually in much more detail than has hitherto been thought possible.

We must not, however, underestimate the difficulties and limitations of the method. While Müller's microscope is a simple inexpensive structure, it is not one which can be opened in order to change the specimen in the way one does on a standard electron microscope. The vacuum conditions are very exacting and so far as is known at present, nobody has succeeded in making such a microscope work in a demountable vacuum system. Another point is that the molecules to be studied must be sufficiently stable not to decompose when they are evaporated over on to the tungsten point. Finally while the resolution and contrast attained by Müller are far higher than that which can be attained with the standard electron microscope in the study of chemicals of this sort, the resolution is still not sufficient to show us the detailed internal structure of the molecules. What we see, in effect, is the gross outline of the molecule.

Background information about this invention is to be found in *Report on Progress in Physics*, Vol. 9, 1942–43.

The Changing Emphasis of Scientific Research

At the recent opening of the new Dunlop Research Centre, Sir Lawrence Bragg said jocularly: "The gadgeteer, like the poor, is always with us. We all know the man who surrounds himself with all sorts of apparatus rather like a caddis worm putting little sticks and stones all round itself and sitting in the middle making a noise like a scientist."

He then continued: "It is a great relief to turn from such people to the saner world of the great men of the past." Sir Lawrence's use of the word 'gadgeteer' and his examples of great work of the past were an apt comment on the way in which the carrying out of scientific research has changed in the past half a century. In early important researches that now rank so often as classical, the apparatus was simple; so was the approach, but the cerebration of the scientist concerned was not. The emphasis was on originality and power of thought, often linked with a craftsman's skill and ingenuity. So little was the apparatus considered

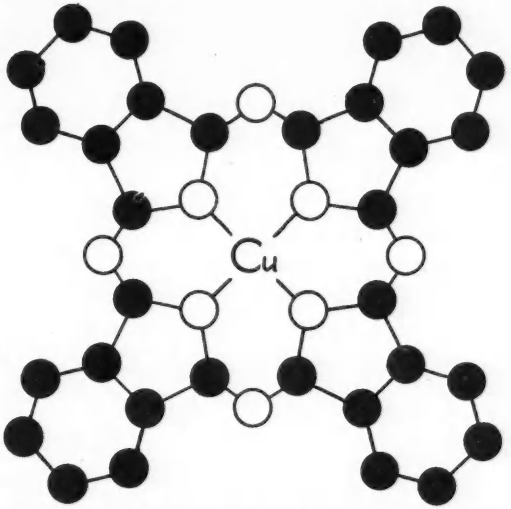


Fig. 2.—A typical phthalocyanine is copper phthalocyanine: the molecule has this structure, black atoms being carbon and the others nitrogen atoms.

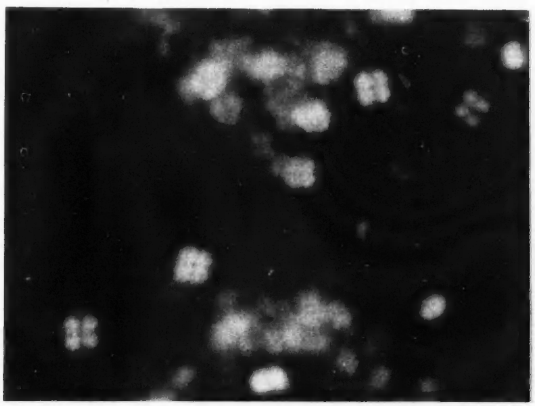


Fig. 3.—The phthalocyanine molecule consists of four symmetrical segments. This symmetry is revealed in this picture taken with Dr. Muller's microscope; each 'hot cross bun' is a phthalocyanine molecule.

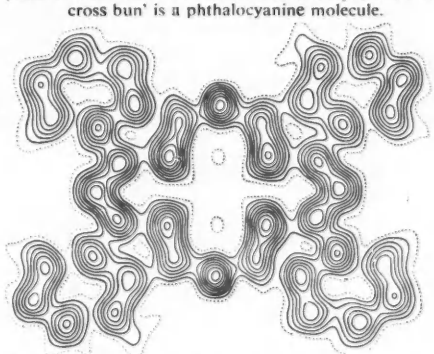


Fig. 4.—The X-ray crystallographer's picture of a phthalocyanine molecule. This is a contour map showing the distribution of electron density; it is very accurate but extremely laborious to produce.

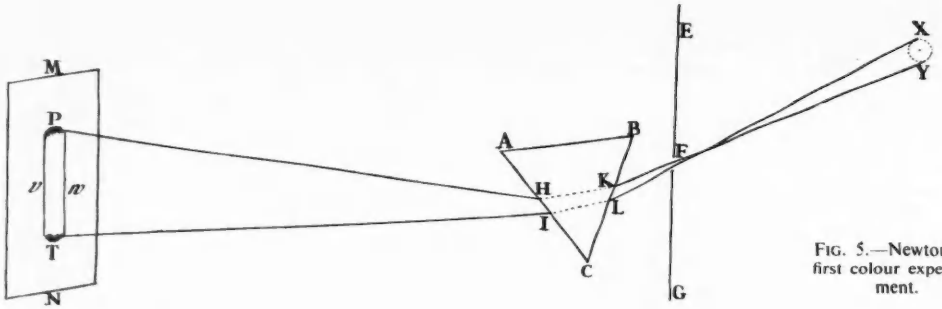


FIG. 5.—Newton's first colour experiment.

important in itself that most of it has disappeared. Today the emphasis is shifting to the complicated gear, so often a feat of engineering; today the visitor to a laboratory is encouraged to see the pile or cyclotron or computing machine or some other shining product with an impressive array of knobs and dials, not the man using it or the experiment being done with it, not the idea being explored. There is, in short, an emphasis on gadgetry.

This has been noted with misgiving by visitors to the annual exhibition of the Physical Society. It has affected the personnel of the scientific world by producing a dozen technicians to every one creative scientist. There is even a certain inevitability about this change because the more we know, the less there is to be discovered at the simpler levels. And some lines of research, notably nuclear physics, cannot be pursued without very large and powerful machines. Nevertheless, it is as well for us to be reminded that most of the classical work of physics has been done with very simple apparatus: the same thing is largely true in the other sciences.

Sir Lawrence Bragg mentioned Fresnel. He was a French engineer who made the greatest fundamental contribution to the wave theory of light by setting it on a logically firm foundation and performing experiments that were unexceptionable. Yet the micrometers he used were made by the village blacksmith, and when he wanted a little lens passing approximately monochromatic light (light of one wavelength) he achieved it by making a hole in an iron plate and placing in it a drop of honey. Sir Lawrence Bragg also mentioned Lord Rayleigh, whose classic work was the accurate determination of the ohm. Rayleigh found that the best way of controlling the speed of rotation of a coil in a magnetic field was to hold the driving belt between his fingers and adjust the pressure as needed; one could imagine, Sir Lawrence went on, what an apparatus, with rows and rows of valves, people would put up today to keep a rotation speed constant.

The ohm itself, the unit of electrical resistance, was named after George Ohm, who in 1826–7 did work that once and for all established the laws of elementary current electricity. His apparatus is shown in Fig. 6. He made it all himself. A magnet swung on gold ribbon from a milled head. Current passed along a conductor near the magnet. The electromotive force was made by holding the junctions *ab* and *a'b'* in boiling water and ice. The small containers for this purpose are not shown in the illustration, but apart from this the *whole* of his apparatus with which he established his laws is shown. When the passage of current caused the magnet to move, it was brought back into alignment by rotating the milled head at the top. The number of degrees through which this head had to be turned to produce alignment was a measure of the 'strength' of the electricity, or what we call today the 'current'.

After Ohm the most important fundamental work on electricity was that done by Faraday. In 1831 he succeeded in producing electro-magnetic induction and thereby laid the foundations of electrical engineering and the power generation of our own time. The apparatus he used consisted of an iron ring with wire wound round it, a magnetic needle, and a battery. With it he established the fact that a *change* in magnetic field produces current in a conductor situated in that magnetic field. This is the basic principle of the modern generator, in which a coil of conductor rotates in a magnetic field. And this was all done with wire wound on an iron ring—insulated by winding the turns alternately with twine—a magnetic needle, and a battery.

Such examples could be increased to make a very long list indeed. Robert Hooke's elementary microscope, inferior to that used by any student today, sufficed—with Hooke's intelligence—to establish, among other things, the cellular theory of living matter. At about the same time Robert Boyle used a glass tube some eight feet or so long, bent at one end to make a J, with the short limb closed at the end, to determine the law known as Boyle's law, an indispensable part of our present gas laws, which are the basis of the theory of gases. The tube was held vertically near the stairs. An assistant on the stairs poured mercury into the top of the open limb and Boyle read the change in length of the air column in the closed limb. That is all. Most schoolboys perform the experiment as a matter of routine today with a slightly smaller tube. Then there is the French engineer Malus, who established for the first time the facts about the polarisation of light by reflection. His sole apparatus was a crystal of Iceland spar that he carried about with him.

We need not confine our examples to work done in past centuries. C. T. R. Wilson, for example, made his first cloud chamber, an indispensable tool for atomic physics, from glass and sealing wax. R. A. Millikan determined the charge on the electron in a classic piece of work in which the charge picked up by a falling drop of oil made it tend to rise in an electric field. This tendency to rise opposed the natural tendency to fall. From the changes in speed resulting from this, the charge on the electron could be evaluated. Millikan received a Nobel prize in 1923 for his

work. He certainly made some use of twentieth-century improvements, but the basic method was simple and his apparatus had that old-fashioned look of all physics apparatus assembled on a bench. Even today, as readers of our July number will remember, the apparatus used by Professor Bridgman for investigating the effects of very high pressures, is very simple, consisting essentially of a small tubular space in which a piston compresses the specimen.

When all the long list of classical work is examined, however, the most remarkable of all in connexion with our present theme, is that used by Sir Isaac Newton. He founded colour science. And he did it with apparatus that at first consisted of one glass prism, by no means a perfect one at that, and a paper screen. Simplification could hardly be taken further. Newton's illustration of his first colour experiment, in which he found that a homogeneous beam of sunlight, instead of giving a circular image, gave a rectangular one consisting of numerous overlapping circular images, each of which gave rise to a colour sensation, is shown in Fig. 5, a facsimile taken from his *Opticks*.

Such experiments as these remind us that a scientist's task is to explore natural phenomena and develop ideas about them, not merely to make use of elaborate machines. This simple fact was probably in Sir Lawrence Bragg's mind when he referred to the relief he felt in turning to the saner world of the great men of the past.

Are these Insecticides too Toxic?

In the quest for better and better insecticides, the secondary toxicity of these substances for man and animals requires as much investigation as their lethal effects upon crop pests. This is not a new problem, but it is one that has been intensified by the discovery and rapid development of a large number of entirely new and mainly synthetic insecticides. The dilemma presented by these useful poisons, ancient and modern, would be easily resolved if it was merely a case of killing insects with concentrations far below those 'dosage rates' likely to affect human or animal health. Unfortunately, this is too superficial an assessment of the problem. There is the question of cumulative toxicity to man; there is the question of varying human susceptibilities to the same dose; there is also the question of toxicity when the insecticide material is being handled, often in concentrated form, before dilution to make the insecticidal spray. Indeed, there has perhaps been too much attention to the danger of minute residues upon crops, and too little to the risk of spraying operators being poisoned.

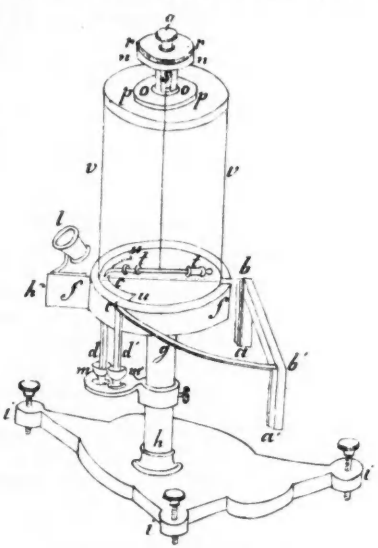


Fig. 6.—Ohm's apparatus.

No measures can protect the fool who, knowing he is handling a poison, gets it mixed with his food or drink, and any accident of this kind cannot be blamed upon the insecticide. But there are more insecticides of the contact type than of the stomach poison type; that is, they kill insects by skin or cuticle penetration, or by inhalation. When very minute doses are sufficient to kill insects in large numbers, it is always possible that somewhat larger amounts can have dangerous or even fatal effects upon human health through skin absorption or by spray inhalation. It is always possible, too, that frequent exposure to this risk will lead to the building-up in the human system of a toxic concentration, suddenly revealing itself in serious illness.

One new class of synthetic insecticides—those based upon complex organic compounds of phosphorus—would seem to carry very high risks of this kind. Although these substances are outstandingly effective in controlling certain insect pests, notably aphids, and the red spider (which DDT does not poison), they are also powerfully and insidiously toxic to man and animals. To some extent it would seem that these insecticides have been introduced before these dangers have been sufficiently assessed, and it is possible that users will not know, let alone take, the necessary precautions. The three main substances of this class are HETP, TEPP, and parathion.* In the United States one of the scientific pioneers of parathion collapsed and died quickly after taking part in a parathion spraying operation. Dr. Donald Hunter has written of these products: "All types of preparation penetrate rapidly through the skin, producing only slight irritation at the site of absorption. Exposure to as little as 0·3 gramme daily has been estimated as dangerous to man."

After actual application, HETP and TEPP are certainly as safe as nicotine, for on mixing with water both hydrolyse to form non-toxic substances; just as nicotine residues evaporate on the plants, so the dilute solutions of these synthetic insecticides gradually lose all toxicity. Even to insects they are lethal only for a short time. But this is an advantage with a dangerous consequence. These substances must be sold in their 'neat' or undiluted form, and the user must make up his own spray solutions; a drop or a smear of the undiluted liquid upon the skin during the spray-making operation could have very unpleasant results. Nicotine, on the other hand, can be sold in diluted liquid base forms or as 4% dusts, thus ensuring that the public

* HETP and TEPP are liquid mixtures in which the active ingredient is *tetra-ethyl pyrophosphate*; roughly in 20 and 40% amounts respectively. Parathion has been produced to 95% purity, but most samples are crude mixtures of 70% purity. The active ingredient is *para-nitrophenyl diethyl thiophosphate*.

need not handle the concentrated poison. Nevertheless, HETP and TEPP preparations can be bought today by any member of the public; no signature on the Poisons Register is required, and these insecticides are often recommended for the control of aphis attacks in gardens. The amateur gardener has all too little knowledge of the toxic material he is handling.

Parathion is even more dangerous. Commercial samples are crude mixtures containing 70% or more of the supposed active ingredient, and this ingredient is itself highly toxic to man as well as to insects: other closely related substances which have much greater toxicity to humans *may* be in the total mixture. Heat, for instance, transforms some of the thiophosphate into new molecular arrangements (isomers) which are less insecticidal but far more toxic to humans; yet parathion is being developed in pyrotechnic smoke generators for control of glasshouse pests. Parathion was first developed in wartime Germany as 'E. 605' (chemical name), but it is now believed that some of the more promising results recorded in Germany are actually obtained with a chemical relative of parathion, a slightly different organo-phosphorus compound which has a lower toxicity to humans. These are all matters requiring further research, and until there is more certainty about the chemical constitution of these mixtures which are called parathion it is impossible to assess the risks to man that are associated with their use.

Should the use of these insecticides be banned? This has been suggested in America and in Britain As their use in controlling aphids is so promising, total abolition must be regarded as precaution in excess. Instead, there should be restrictions upon their general use. The responsible government departments are debating what should be done and it is to be hoped that a decision will be speedily forthcoming. Let us hope there will not be the same sort of delay as marred the decision over agene. In the meantime amateurs would do best to leave these insecticides alone.

Colorado Beetle in Britain

FOLLOWING close upon a press announcement on May 16 that large numbers of Colorado beetle were being washed ashore on beaches of the Channel Islands, came the news that in Belgium, beaches near Ostend were littered with the bodies of millions of these pests. All through the summer the invasion has continued, though in such small numbers that it means no serious menace to our potato crops.

Every year at the end of May, swarms of these beetles leave their hibernation places in search of fresh breeding-grounds, and owing to the prevailing winds many swarms are blown over the Channel. The Colorado beetle is a poor flier; it is unable to remain airborne for longer than fifteen minutes and so these swarms fall into the sea usually less than ten miles from the French, Belgium or Dutch coasts. Often the insects fall on to the decks of fishing vessels, and the riggings of cross-Channel steamers are frequently infested with the exhausted insects. Reports in 1947 tell of 'beetle-bergs' floating at sea, some measuring 8 ft. long by 6 ft. wide and composed of beetles piled one upon the other to a height of 6 in. to 9 in. Provided that the females have not laid their eggs before falling into the sea, they can survive unharmed for up to ten days at sea. Even after six days on the water the female will clamber on to seaweed to lay her eggs, and if the weather is warm enough surviving beetles washed up on beaches will fly inland and lay their eggs.

Naturally, we in Britain want to know how these swarming flights affect our own agricultural communities. It will be surprising indeed if some of the beetles now active across the Channel do not reach the coasts of Kent and Sussex this year. In former years a few Colorado beetles have been washed ashore there, but it is unlikely that survivors of the present swarms or their descendants will live long enough to cause more than a little local damage to potato crops.

The beetles chiefly enter this country upon imported green vegetables—rarely upon imported potatoes—or they may arrive at East Coast ports on vessels from France, Belgium or Holland. In 1948, for example, 279 beetles were captured aboard ships coming from these countries; two others were taken at Northolt and Heath Row airports; a few beetles were found on pit props from Canada, whilst a single adult was discovered aboard the *Aquitania* in mid-Atlantic. In the same year, 38 beetles were found upon imported greenstuffs, and in general, finds of single insects are made in precisely those areas of Britain to which imported vegetables are distributed.

On potato crops inland 57 breeding colonies of the beetles were confirmed during 1947; the following year saw a vast improvement when only 11 colonies were found. Fortunately in Britain there are few wild plants on which the insect will feed, and the main danger from this aspect is where small colonies remain on stray potato plants growing amongst other crops. When an infestation has been reported and confirmed, Ministry of Agriculture Inspectors examine every potato plant on the infested site, and search for all stages of the beetle in nearby fields or gardens where potatoes are grown. The eggs, grubs and adults are hand-collected, the infested plants are lifted, dusted with DDT and buried. As a further precaution, the soil immediately surrounding the infested plants is injected with carbon disulphide fumigant to destroy pupae or grubs resting below ground level. The remainder of the field and the crops within $\frac{1}{2}$ to 1 mile radius are then dusted or sprayed with DDT. A careful watch is kept on the neighbourhood during the rest of the year. The next crop taken from the field is again potatoes, the second crop acting as a trap to survivors of the treatment, but to date no beetles have been found in these circumstances. Sometimes, as happened recently at Dartford and Hartlip, the area treated is not sufficiently great, for in these two places colonies of the beetles were found half a mile beyond areas treated the previous year.

Routine 'protective' treatments are given to potato crops in the neighbourhood of certain ports, the Thames Estuary, and in places where treatments were necessary during the previous year.

Undetected, the Colorado beetle might become an important pest in Britain, as it is in America and on the Continent. Probably a new generation of adults would appear in July, and the second generation of larvae would be found feeding on potato foliage until mid-September. Provided the autumn was warm enough pupation of these larvae might occur, but it is doubtful whether this second generation would be completed under British field conditions.

Programme for Fire Research

A. GRAHAM THOMSON

No doubt the Great Fire of London could have been localised by firemen with modern equipment operating from hydrants at convenient points. Nevertheless extensive damage could scarcely have been prevented, because the London of those days was full of tiny wooden houses, crowded together in narrow streets. Once the fire started the wooden houses blazed like paper and the flames spread rapidly from street to street. Since there were neither telephones nor fire alarms, a very large area would have been ablaze before our imaginary firemen with their modern equipment could arrive.

Despite the new hazards created by electricity, petrol and highly inflammable chemicals, the construction of more fire-resistant buildings has eliminated the possibility of a disaster approaching that of the Great Fire. Nevertheless last year the estimated damage to property in Britain by fire exceeded £22 millions. Many of these fires were preventable, and it is with prevention rather than extinction that contemporary research is primarily concerned.

More than fifty years ago systematic studies of fire resistance were started by the British Fire Protection Committee. One of the main results of this work was recognition of the need for a standard procedure in tests of fire resistance. In order to provide the necessary facilities for such tests a Fire Testing Station was established at Boreham Wood, Elstree. This station was built by the Fire Offices' Committee in 1936 and was immediately made available to the Building Research Station of the Department of Scientific and Industrial Research for work on the fire resistance of buildings and structural elements. Four years later the D.S.I.R. established a Fire Fighting Research Section at the Building Research Station.

The war altered the character of fire research, but as the end drew near, the Fire Offices' Committee and the D.S.I.R. both expressed their intention of resuming their peacetime work. Discussions between the two bodies led to the formation of a Joint Fire Research Organisation, which was established in 1946. On January 1, 1947, Mr. S. H. Clarke, M.Sc., was appointed Director of Fire Research.

As part of its contribution to the capital cost of the new venture, the Fire Offices' Committee placed at its disposal the station at Boreham Wood, which comprised a large hall for fire resistance tests, another building which housed equipment for hydraulic tests on sprinkler apparatus, a small chemical laboratory, and a suite of offices. Temporary laboratories have since been erected and it is intended to add further offices, workshops and laboratories as opportunity occurs.

The purpose of the Joint Fire Research Organisation is to carry out all research necessary to reduce the hazard of loss of property by fire. Its investigations cover the causes of fires, the behaviour of materials in fires, fire-resistance of building constructions, and finally fire-fighting equipment and technique.

Of basic importance to this very wide field of research is the collation and analysis of statistical information on current fires in order to determine the relative importance of the factors which result in damage. The Intelligence Section has therefore arranged with the Home Office that any fires attended by fire brigades should be reported to it in such a manner that the information can be filed on punched cards for mechanical sorting.

Normally there are about 70,000 fires in Britain every year. In a hot, dry year this average may be considerably exceeded; in 1949, for instance, there were more than 100,000 fires. From more than 400,000 reports already received the Intelligence Section prepares tables showing the types of buildings, industries, etc. in which fires started, the supposed causes,* the method of extinction, and any other significant information.

The system adopted enables virtually any information required for operational research to be very rapidly extracted. Data regarding any particular type of risk is also supplied to other Government Departments and to any authentic organisation with a fire problem. For example, a statistical analysis of the information available on fires in ships in port, or in shipbuilding and repair yards, was prepared for a Working Party set up by the Ministry of Transport.

Both the Physics and Engineering Sections of the Joint Fire Research Organisation are extensively engaged in studying the fire resistance of buildings and building constructions generally. New types of flue construction in prefabricated houses present possible hazards, which must be assessed. The use of prestressed concrete calls for special study. This material enables a considerable saving in weight to be effected as compared with reinforced concrete, but due to the use of thinner constructions the thermal protection afforded to the steelwork in buildings, is reduced to less than a third. It is desirable, therefore, to determine whether any additional protection or any modification of design is required for fire protection. Experimental floors have been constructed for test purposes, using different types of fire protection. Supplementing this work is an investigation to determine the particular type of failure of prestressed concrete in fires, so that it may be possible to design the most economic element of structure with adequate fire resistance.

Many of the more spectacular tests are carried out in the furnace room, which is a fire-resistant building constructed of reinforced concrete throughout, including the roof. This building is equipped with three huge gas-fired furnaces.

One furnace is used for testing structural columns. In appearance it resembles an enormous jam-jar ten-foot high, constructed in two halves which close together and surround the column under test. The load is applied to the column by means of a hydraulic jack at the base of the column, which is required to support 1½ times the load it is designed to carry. Plain steel columns can withstand fire

* Statistics for 1947 show that 6740 fires in buildings were due to sundry materials being ignited by a fire in a grate, 4300 to smoking materials, 2598 to electric wires and cables—and 2280 to children playing with matches! More than fifty known causes are listed, static electricity accounting for two fires and the sun's rays for 117.

for only about ten minutes before collapsing. Steel columns, protected by concrete for instance, however have to stand up for periods ranging from one to six hours, depending on the type of building for which they are intended.

In a second furnace, partitions and walls of buildings are tested. This furnace is constructed in such a way that a large number of materials can be rapidly tested by building them into a partition in one of the furnace walls. The two halves of the furnace are brought together, and the partition or wall is exposed to numerous gas jets until it disintegrates.

The third furnace is for testing floors and ceilings, loads being evenly applied to the floors by means of cast iron weights.

The times taken for constructions to collapse in the furnaces are noted, and by this means the fire-resistant properties of different materials and structures are compared. From the knowledge thus gained, standards for constructional materials are laid down.

Many authorities insist on new constructions being tested by the Joint Fire Research Organisation before sanctioning their use. Manufacturers and architects are also able to take advantage of these tests, which assist them to achieve the most economical designs capable of reaching the required standards.

Attention is also given to the fire-resistance of steel bulkheads with various protective coatings and of other materials for ship construction. From experience gained of fires on land it has been possible to lay down standards of fire resistance for ships.

While the three large furnaces dominate the testing room, the same building is equipped with apparatus for a variety of other tests. A small furnace has recently been developed for determining the readiness with which paints and other materials used for surface finishes will contribute to the rapid spread of fire. The specimen is fixed at right angles to a gas fire radiation panel and a 7-in. gas flame is applied for one minute to the surface of the specimen on the end near to the radiator. The rate at which the flames spread across the material is noted.

Since there is still insufficient basic information to warrant complete reliance on small-scale experiments, fire resistance tests are conducted on full-size elements of structure wherever possible. A standard room has been constructed, and is equipped with standard rough wooden furniture to extend the information on the behaviour of constructions involving a combination of structural elements. Here various types of constructions for doors, ceilings, roofs, etc., are given full-scale tests. A fire is started on a home-made chair and thermocouples in the walls and ceilings enable accurate observations to be made.

On the theoretical side an electric analogue has been designed which reproduces by analogy the flow of heat through structural materials, so that the thickness of protection required for any structure can be determined without involved mathematical calculations. Its purpose is first of all to discover what is happening in the specimen under examination, and secondly to shorten the time required for testing. To prepare and test a brick wall takes several weeks. Much time and expense can therefore be saved by carrying out the preliminary tests in the electric analogue.

The Engineering Section is concerned mainly with fire-fighting equipment and technique. Most important of all fire-fighting materials is water, which is the cheapest and best cooling material available because of its high latent heat, as well as the most abundant. It is used in sprinklers, in portable extinguishers, and in various types of appliances employed by fire brigades. The application of water to fire-fighting is therefore studied from numerous angles.

In fighting fires in forests or remote country districts, water supplies are often inadequate or not readily accessible, so that any means of increasing the 'wetness' of water is potentially valuable. Certain wetting agents have been developed, which are claimed to increase the fire extinguishing capacity of water. Experiments are being undertaken to determine whether these chemicals can be of material assistance either in extinguishing fires or in preventing their rate of spread. Wetting agents do not appear to offer any advantages when water is directly applied to fire extinction.

Progress is being made in studies of the water sprays used in fire extinction. An experimental spray is formed by the action of two impinging jets of water. Samples of the droplets collected on microscope slides covered with castor oil are magnified and photographed on a microprojector specially developed for the purpose. The diameter of the drops is plotted on graphs against the velocity of the water coming out of the jet. By determining the mean size of droplet produced from a given angle and velocity of water, it is hoped to improve the effectiveness of sprays for particular applications.

The distribution of spray in a sprinkler system is being studied by measuring the water collected during a given time from a number of tins arranged in varying patterns underneath a central sprinkler.

A 'figure of merit' test for comparing the efficiency of different foam compounds in extinguishing petrol fires was developed at the Chemical Research Laboratory during the war. At that period there was no means of producing foam on a laboratory scale for research purposes. The Joint Fire Research Organisation has now succeeded in developing the only apparatus in the world capable of producing and testing foam on a small scale. Various types of foam supplied by manufacturers are tested on petrol and other liquids. The apparatus consists of a long metal tray, one end of which is filled to a depth of about half an inch with petrol. The petrol is ignited and foam is fed down a chute into the blazing liquid, its efficiency being determined by measuring the distance the foam blanket spreads over the liquid before it is destroyed.

It has been found that foam is effective against flaming liquids which are insoluble in water, but most types are less effective on liquids such as alcohol and acetone, which are water soluble.

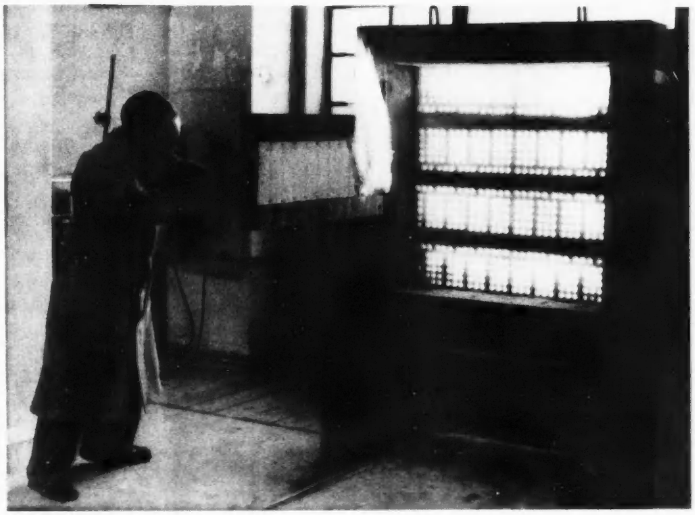
The Engineering Section carries out tests on firemen's helmets and has been closely associated with the development of new and improved designs. New types of fire hose have also been examined, and assistance is given to the Home Office in the preparation of specifications for hose.

The phenomena of ignition and combustion are among the principal problems engaging the attention of the Chemical Section.

For their studies of spontaneous combustion the investigators have developed an apparatus which will be the

first standard instrument for assessing the hazard of any type of material. This apparatus is being used for testing the effects of spontaneous heating on various oils and seeds. A weighed quantity of oil is absorbed by a fibre, which is then surrounded by boiling water. If the oil is not liable to spontaneous heating the temperature will not rise above 100° C., but an 'active' oil will become increasingly hot as time goes on. The activity of the oil can therefore be measured by the rise in temperature within a given time.

Another apparatus has been designed to study the effect of such factors as packing density on a fibre soaked in oil. The air flow through a bundle of fibres is measured and kept constant and the pressure difference across the bundle is also determined. These investigations should assist in reducing such special hazards as spontaneous heating of the oils used for processing wools.



Measuring the speed at which fire spreads over various wall surfaces at the Fire Research Station.

The effects of preheating on wood are determined by heating a specimen in a thermostatically controlled oven for periods ranging from a week to several months. The ignition temperature of a sample piece is then determined. It has been found that this temperature is lower than that of normal dried wood, but not sufficiently low to cause ignition of timber which is subjected, for example, to prolonged exposure to hot water pipes. It has been suggested that when wood is heated for a long period some decomposition takes place, giving rise to an active form of carbon which will ignite at much lower temperatures than ordinary wood.

The combustibility of various woods is studied by exposing small blocks to a gas furnace at a given radiation intensity. Observations show that the time required to ignite the specimens depends mainly on the density of the wood.

The Chemical Section is also engaged on an investigation to determine the most efficient distribution and sizes of droplets for extinguishing oil fires. An apparatus has been designed which enables sprays of known, and approximately uniform, droplet size to be produced, and which permits variation in the size of the drops and in the rate of delivery. The droplet diameters range from 1 mm., the largest provided in firemen's sprays, down to as small as 0·2mm.

Another investigation concerns a rather peculiar hazard presented by the use of aluminium paint on rusty iron. Specimens of iron coated with various paints are placed in a sealed box which is equipped with a striker. The top of the box is covered with a transparent material and a mixture of coal gas or hexane is passed through. The specimen is then hit with the striker and continues to be struck until an explosion takes place and bursts the cover. If a specimen is struck fifty times without exploding its performance is considered satisfactory.

Certain materials such as carbon tetrachloride and methyl bromide are capable of modifying the inflammability of liquid fuels or reducing the hazards of explosive atmospheres. For the latter purpose they might be used in the open or in a closed space such as a transformer house, involving the necessity for calculating how much inhibitor should be added to make an atmosphere non-inflammable. It is necessary, therefore, to determine the quantitative effects of inhibitors on explosive atmospheres and to consider their use in any particular application. A constant flow apparatus has been constructed for determining the effects of inhibitors on inflammable gases by allowing a flame from a pilot jet to pass through a tube containing a mixture of combustible gas, inhibitor and air. The limit of inflammability is reached when the gas just fails to ignite. By means of this apparatus the efficiency of various potential inhibitors can be compared. Toxicity is an important aspect of some fire inhibitors. The Joint Fire Research Organisation does not carry out any experiments on toxicity, but consults the Medical Research Council whenever necessary.

Firemen often find that smoke presents a greater hazard than the fire. The problem of smoky atmospheres is therefore being investigated in order to explore the possibility of improving the fireman's view in smoke. From the experiments so far undertaken the main conclusion reached is that no immediate prospect of any spectacular improvement exists.

Additional to its own research programme, which includes many investigations not mentioned in this review, the Joint Fire Research Organisation deals with numerous technical inquiries from Government Departments, commercial firms and other bodies. Queries which can be answered from existing information are referred to the Fire Protection Association, with which close collaboration is maintained, but in many instances experimental work or tests are undertaken.

The staff of the Fire Research Station numbers sixty-five, and includes some twenty science graduates. The station's annual income is of the order of £50,000.

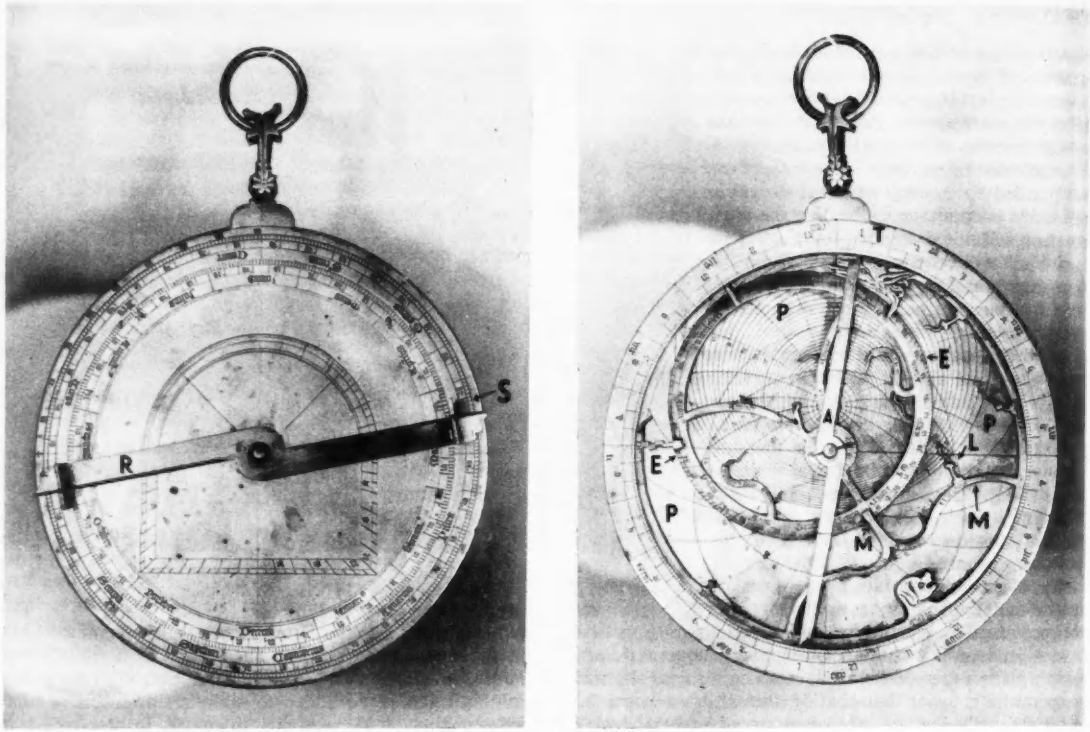


FIG. 1.—Telling the time by a fourteenth-century astrolabe (now in the Museum of the History of Science, Oxford). FIG. 1*a* (*left*).—The astrolabe is suspended vertically and the rule R with sights is turned until the star chosen (in this case *Cor Leonis*) is seen through them. The altitude is read off on the scale S; in this case it is 8°. FIG. 1*b* (*right*).—The astrolabe is turned over and the movable star-map M is rotated until the pointer L marked *Cor Leonis* lies on the altitude circle marked 8° on plate P. The date being the 20th day of Scorpio, the rule is turned until it lies on the point of the eccentric circle E (showing the sun's position) marked with that date. The time 12.30 a.m. is indicated by the rule A on the rim T, graduated in hours.

Mediaeval Scientific Instruments

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WE are inclined to think of the invention of scientific instruments as characteristic of the 16th and 17th centuries, and so indeed it was; nevertheless the men of the revival of learning in the 12th and 14th centuries invented or brought into use a number of devices that are of fundamental importance, at least as ancestors of the more perfect instruments of later times. Some of these, such as the mechanical clock and the magnetic compass, may have been their own invention; of others, such as the astrolabe, they derived their knowledge from the Arabs. In this article it will be our purpose to consider the thing rather than its source.

We may begin with the instruments used in astronomy, which was a science of perennial interest, first in itself, secondly because it was the means of time-telling and navigation, thirdly because it was required for the art of astrology by which men steered their way through the troubles and chances of an uncertain and dangerous life. Let us first consider time-measurement.

All time-measurement was based on the movement of the earth in the heavens, whereby the sun and stars appear to move round the earth at a uniform rate, and therefore to describe circles with the pole star as centre. Seen from any point in the world as known to the Middle Ages, they seem at once to move round the horizon, *i.e.* in azimuth, and to ascend and descend the heavens, *i.e.* to alter in altitude. Each of these movements can be used to measure time.

The best means of telling the time known to the men of the Middle Ages was the astrolabe, which was an altitude-instrument for use with the sun by day and the stars by night. Some form of the astrolabe was used by the Alexandrian Greeks, about A.D. 500 and perhaps earlier, but since none has survived it is not certain how closely their instruments resembled the existent astrolabes of the 10th century and later. Astrolabes were used by the Arabs and Persians in the 10th century A.D., and were later

introduced into Spain by the Arabs. From Spain they spread over Europe, reaching England in the 14th century.

One side of an astrolabe (Fig. 1*a*) is simply a circle graduated in degrees, with a movable pointer bearing a pair of sights. By suspending the instrument vertically from the thumb and viewing a selected star through the sights its altitude could be read off. The altitude of the sun could also be measured by letting a ray fall through the pinholes of the two sights.

The other side of the astrolabe (Fig. 1*b*) is an ingenious device for finding the time from the altitude of the heavenly body selected. It consists of an outer scale of hours, an elegantly fashioned skeleton star-map that can be rotated about the pole star, and a fixed plate beneath it showing a projection of the circles of altitude for the latitude where it is to be used. Above all is a movable rule. The most conspicuous stars are shown on the map by named pointers and the position of the sun among the stars by an eccentric circle graduated in days. By turning the skeleton map until the pointer corresponding to the body observed indicates on the fixed plate the altitude at which it was observed, the sun is correctly sited with respect to the earth's axis; and as the sun may be thought of as the hand of a 24-hour clock travelling round that axis, the pointer from the pole star through the sun to the hour-circle gives the time. The adjustment is merely a matter of seconds, no calculation is required and the time is given with an accuracy of *c.* 2–5 minutes.

Did the men of the Middle Ages understand all this? A few did so, but there was really no need to. We do not have to know how a watch works in order to tell the time, nor did our ancestors have to know the geometry of an astrolabe in order to use it.

The astrolabe shown in Fig. 1 was made in England about 1390 and is almost exactly similar to that which Chaucer sent to his son Lowis, aged 10 and a student at Oxford, together with an admirable treatise on the way to use it.

Astrolabes were used for many purposes other than time-telling. They were used by navigators to find the latitude, being in fact precursors of the sextant, and also by surveyors to measure both altitudes and horizontal angles. The mariner's astrolabe has only the graduated circles and sights: it is made very heavy and parts are cut away to decrease the effect of the wind upon it.

How did the mediaeval instrument-maker graduate his circles? We do not know, but we gather that in the 16th and 17th centuries the circle was geometrically divided into quarters and sixths—and the craftsman then just graduated it! It was in fact a piece of tradesman's knowledge. I imagine he cut off his arcs for the twelfths and bisected these and then adjusted his dividers to cut these up into threes and finally put in the single degrees by eye. Actually the gradations appear to be very regular.

Those who did not use astrolabes used dials. Dials are of great antiquity, being known in ancient Egypt and all subsequent civilisations.

The earliest type, in use in the early Middle Ages, was the wall-dial, consisting of a peg at right angles to a south wall and lines radiating from it (Fig. 3). No attempt was made to draw these lines so as to give true hours. They necessarily gave 6 a.m., 12 noon, and 6 p.m. solar time correctly: but any intermediate line would do as an arbitrary mark to give, for example, the time of Mass. The Bewcastle dial of the 7th century has 12 hour-lines at equal angles, but most of them have only five graduations intended as 6, 9, 12, 3 and 6. These gave the time corresponding to the canonical hours. Matins and lauds were before it was light and the five markings correspond to prime, sext, none, vespers, and compline.

We also find another sort of dial which had the advantage of being portable. It consists of a vertical rod, with a scale of hours for each month, in which a peg can be inserted (or an index turned) so as to be at the top of any one of these scales, when the shadow of the sun will extend as far down as the hour-line corresponding to the time of day. The oldest example (Fig. 2) was dug up in Canterbury Cathedral in 1938. It is of silver with a gold mounting and dates from the 10th century. Later dials of this type were cylindrical, (thus Chaucer alludes to one of these as a chilindre, *i.e.* a cylinder, in the Shipman's tale,) and these instruments remained in use till modern times in the Pyrenees.

A third type is an ordinary sundial set on a base

FIG. 2.—The Canterbury Cathedral sundial.

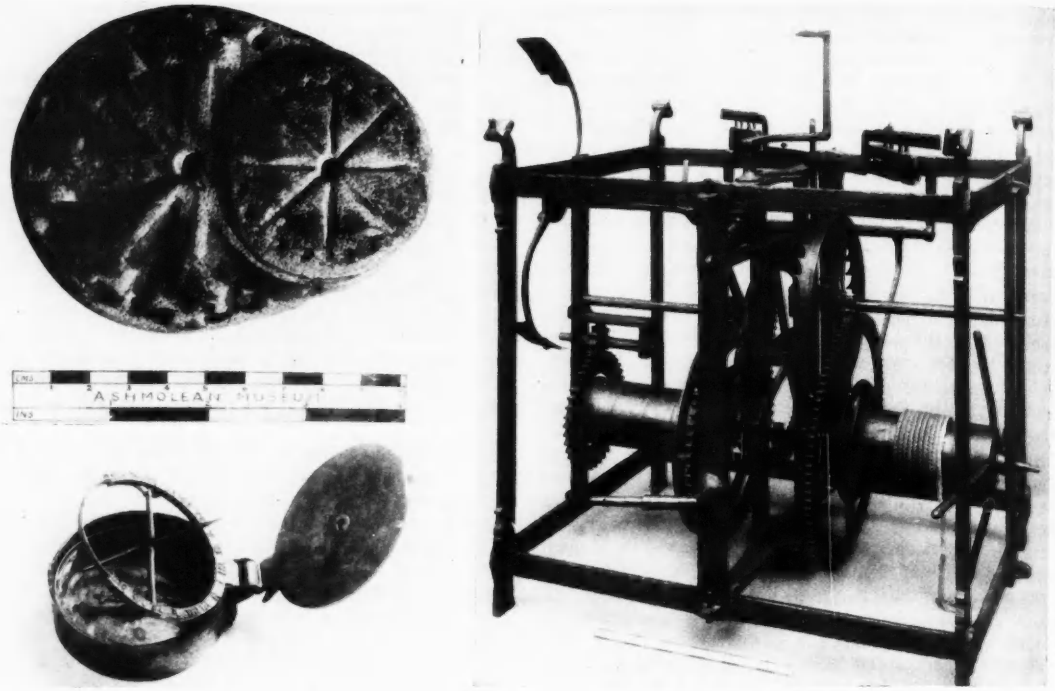


FIG. 3 (*Top*).—A mediaeval wall dial. No attempt is made to project the hour-lines geometrically, nor was the missing gnomon directed at the pole star, as in all later wall-dials. FIG. 4 (*left*).—Spanish compass-dial, probably *c.* 1400 A.D. It is orientated in the N—S meridian by means of the compass-needle. The ring is erected to the co-latitude of the place and the needle, at right angles to its plane, casts the shadow. FIG. 5 (*right*).—The Dover Castle Clock, A.D.1348. (*Science Museum photograph.*)

containing a compass-needle. The antiquity of these is uncertain but examples are known which appear to date from about 1400, as does the Spanish example shown in Fig. 4. This incidentally contains what may be the oldest surviving compass. In later years they became the most popular type of time-telling instrument. In the period round 1450 the geometry of dialling began to be well understood and many new types appeared; these, however, belong really to the Renaissance rather than the Middle Ages.

How could time be measured when the sun and stars were invisible? We hear of the water-clock, the *clepsydra* of the ancients, and possibly the clock said to have been made by Gerbert (Pope Silvester II) before A.D. 1000, was of this type. I have not, however, seen any evidence that it was a common instrument in the Middle Ages. The sand-glass is not mentioned before A.D. 1400; certainly none of the scientific writers of the 13th century alluded to it.

Perhaps the most remarkable of mediaeval scientific inventions is the mechanical clock. I will not go into its uncertain history, but it is known that there was a clock put up at Westminster in 1288. There is a tradition that the clock made by Richard of Wallingford *c.*1325 was the first to be constructed in England: this may be true, for we do not know that the clock at Westminster was made here. The earliest surviving British clock, the Dover Clock (1348), is at the Science Museum (Fig. 5); the Combe Clock in Oxford's Museum of the History of Science is of the same date. These were regulated by an oscillating bar (foliot) with the crown-wheel type of escapement. They had not, as a rule, a clock-face, for few people could have told the time by it, but were designed to operate a striking mechanism. Their effect on astronomy was apparently slight for they do not seem to have been used in that connexion until the time of Tycho Brahe.

The astrolabe and quadrant could be and were used for astronomical observations, but they were only suitable for determining altitudes. Several other types of graduated circles equipped with sights were devised in the 13th and 14th centuries, but as far as we can see they were all small instruments incapable of measuring with accuracy better than *c.* 30′ of arc.

The men of the Middle Ages gave serious attention to one branch of physics, namely to optics. Their knowledge came from Euclid's and Ptolemy's works on the subject and another treatise, *On burning mirrors*, by Diocles. This knowledge was taken up by the Arab Ibn al-Haitham, known as Alhazen, about A.D. 1000, and was transmitted to the West in the 13th century. The mediaeval knowledge of the transmission of light, of shadows and of reflection was pretty accurate: they knew the law of reflection and applied it to plane, spherical, cylindrical, conical and parabolic mirrors. We know that they had burning-mirrors, which were rare and precious treasures. Thus Roger Bacon tells us:

> Also I have indicated above that this kind of congregation [of rays] can be done by reflection, and that a mirror has already been made as an example and indicator of this miracle of nature, so that the possibility of such a work may be seen. But it was made with great expense and labours; for it cost the maker a hundred Paris pounds and he worked, for many years, giving up his studies and other necessary work. Yet he would not have wished to have neglected the work, not for a thousand marks, both for the most beautiful power of wisdom, which he attained, and also because he was thus enabled to make them better and at less cost, because he learnt by experience what he did not know before. Small wonder if he spent so much and laboured so hard in the first work, for never had any of the Latins known how to attempt it . . .

Alhazen, much of whose work was copied by Witelo, about 1270, tells us of what may perhaps be called the first laboratory instrument in physics, designed to investigate and demonstrate the path of reflection of light from different types of mirrors. This I may illustrate by a drawing (Fig. 6) since no intelligible figure is extant.

It consisted of a thick graduated wooden circle perforated radially by tubes. A mirror was set in a thick wooden upright block and light from a hole in a shutter was allowed to enter through one tube. Observation indicated the particular tube through which it was reflected, and the angles of incidence and reflection could be read off. The importance of this instrument is considerable since it may be the first piece of physical apparatus intended to elucidate a law, as distinguished from observing a natural phenomenon, and it demonstrates a truly experimental spirit.

The law of refraction was not quantitatively stated in the Middle Ages but was qualitatively understood. The optical writers before *c.* 1270 talk about the concentration of light and the magnification of bodies by glass spheres, but they do not mention lenses. We first certainly hear of these about 1270, and the discovery of spectacles came a few years later. Lenses were known to Bacon, who says:

> If a man looks at letters and other minute things through the medium of crystal or glass or other transparent matter placed over the letters, and it be a lesser portion of a sphere whose convexity is towards the eye and the eye be in the air, he will see the letters far better and they will appear bigger to him . . . And so this instrument is useful to the old and those who have weak eyes.

This clearly indicates a magnifying-glass and not spectacles. Even magnifying-glasses must have been a rarity, for Bacon sent one to the Pope, with the message:

> The boy John has brought a spheric crystal for experiment and I have instructed him in the demonstration and figuring of this hidden thing. Nor is there anyone in Italy nor two in Paris, who could give a proper explanation of this matter.

The earliest records of spectacles, however, date from a few years after Bacon's time. Thus in 1305, a Dominican friar said it was not twenty years since the art of making spectacles was invented, and that he himself knew the inventor; Francesco Redi in 1678 quoted a manuscript dated 1289 in which the writer says he cannot read or write without the glasses called 'occhiali'.

In 1284 the by-laws of the Venice guides refer to 'roidi da ogli' as well as 'lapides ad legendum'. We may, I think be fairly confident as putting the invention of spectacles as after 1280, but it must, I think, be supposed that no small amount of experimentation with lenses preceded this discovery.

It is widely stated that Alhazen, Roger Bacon, Witelo and John Peckham were acquainted with the camera obscura; this must not be thought to mean that they were acquainted with the casting of an image by means of a lens. The most that they can be supposed to have understood is the casting of an image when light enters a dark room by a small aperture. Aristotle knew that sunlight passing through a hole gave a circular image of the sun and that during an eclipse this image became lunate; the fact and its explanation was known to Alhazen and those who followed him, but I do not think they can be credited with constructing an instrument to show real images. In fact I have been unable to find any passage that implies any knowledge of the formation of such images.

After the clock the greatest mediaeval discovery was the compass. There is, I think, no real evidence as to the source of the discovery. The Chinese knew of the directive power of the magnet long before this time, but we do not know that they made a compass. The earliest certainly authentic account is French (*c.* 1200): there is an English

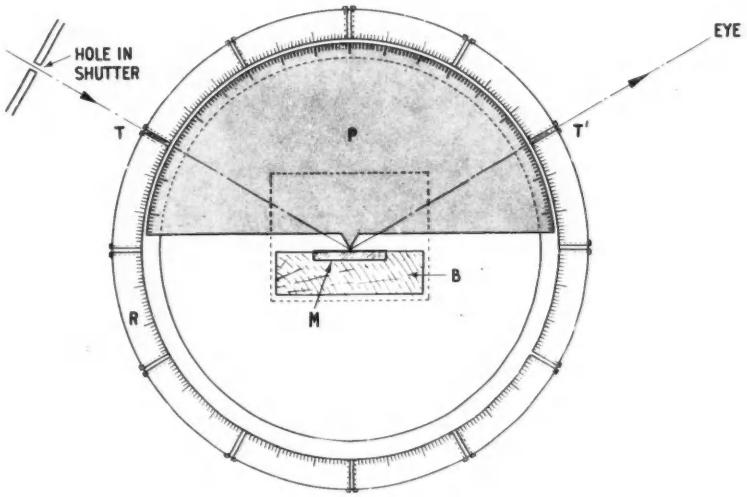


FIG. 6.—The instrument used by Alhazen and Witelo for studying the laws of reflection. R is a thick wooden ring graduated in degrees and pierced at regular intervals by tubes, T, T¹. A wooden block B is recessed so as to receive an iron mirror M. The plate P is so shaped that its point is at the centre of the circle and the mirror is made to touch it. Light from a hole in a shutter is allowed to pass through the tube T and is seen to be reflected through the tube T¹. The angles of incidence and reflection can be read off on the graduated rim R.

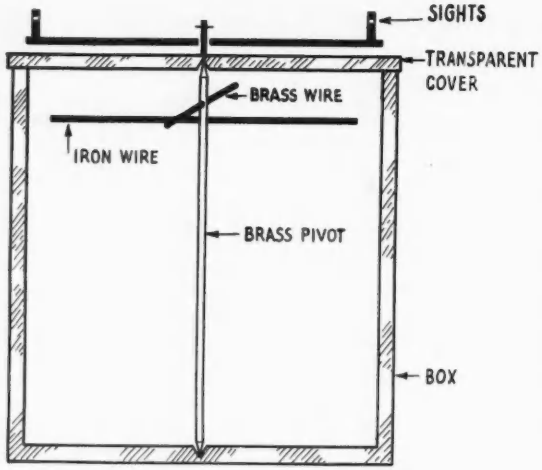


FIG. 7.—Reconstruction of the pivoted compass described by Petrus Peregrinus in A.D. 1269. The needle was passed through a vertical brass pivot which turns in two sockets in the top and bottom of the case: the horizontal brass wire is intended as a pointer to show east and west. The transparent top was graduated in degrees and the sights served to take a bearing.

account in 1207, and an Icelandic one about 1213. The Arabs undoubtedly had the compass at an early period; some authors put this as the 9th century A.D., but this early date is probably an incorrect deduction from a doubtful passage which may not refer to a compass but only to a magnet. Bailak of Kibdjak (al-Gābājāqi) tells us that in 1242 he saw the Arab captains make a compass, consisting of a needle driven into a cornstalk floating in water. Yet we cannot trace the Islamic use of the compass to a period as early as the French or Icelandic.

All we can surely say is that the earliest allusions to the compass, other than Chinese, date from about 1200 and that the knowledge was widely diffused through the Islamic and Western world during the 13th century. The typical account of the compass of the mid-13th century is as follows: the magnet (*i.e.* the loadstone) can impart its 'virtue' to the iron. It has two poles, *anguli*, one of which is called *zoron* and tends to the north: if iron, floated on water, *e.g.* in a straw, is touched with this, the part touched will tend to the north. The opposite corner of the magnet, called *aphron*, tends to the south, and if the iron is touched with it, it will tend to the south.

At this period compasses were not kept ready for use, but when clouds covered the sun and stars and land was out of sight, a compass was made by taking an unmagnetised needle, driving it into a piece of wood or straw and floating it on a pot of water: one end was then 'touched' with a pole of the loadstone, which was then drawn away in such a fashion as to set the needle swinging. That end would then point to N. or S. according to the pole used. The effect must have been very feeble and uncertain. I do not find anything about systematic magnetisation by rubbing the needle with the loadstone in one direction, though we cannot say that the sailors did not practice it.

The pivoted compass is first described by Petrus Peregrinus in 1269 in his remarkable *Letter on the Magnet*. His instrument (Fig. 7) consisted of a box with a transparent lid. The lid and base had sockets in which a vertical brass wire axis could revolve. Through a hole in this axis was inserted the iron wire which was to be magnetised and a wire of brass at right angles to it. On the transparent cover were gradations and an alidade and sights for taking bearings. These are also found on the old Spanish compass shown in Fig. 4. It seems that Petrus was hinting at something more elaborate than a simple mariner's compass, for he talks of turning the alidade to the sun by day or stars by night, and his probable intention was not to make a navigational instrument but a means of telling the time by the compass and the sun.

It remains to speak of chemical and medical instruments. It is hard to know what inventions to ascribe to the mediaeval alchemists. Their principal instruments were the furnace, the still and the reflux condenser, and all of these are to be found in the works of Greek and Arabic alchemists. However, the distillation of alcohol is the chief chemical discovery of the 13th century and we find that the men of the period adapted their stills for the first time

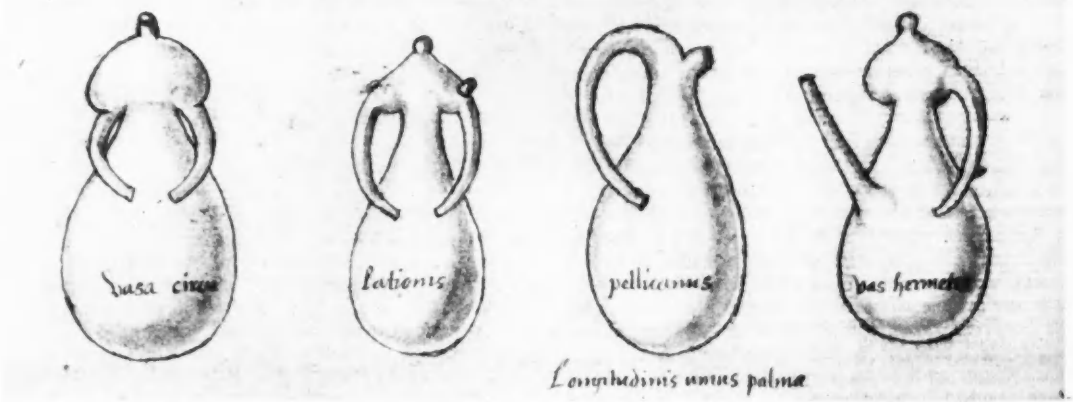


FIG. 8.—Mediaeval circulatory vessels as used in the 14th century (from a 15th-century MS. in the Bodleian Library; from *The Alchemists*.)

for the distillation and condensation of readily volatile liquid. The treatises attributed to Ramon Lull but actually written about 1330–1350, a few years after his death, are very interesting in this respect.

Wine had been distilled and an *aqua ardens*, a "water which would burn" had been extracted from it at a date which is disputed, but which is at least a century and probably several centuries before the Lullian treatises were written. Yet this distillate does not seem to have attracted much attention and was, so to speak, a chemical curiosity. In the 13th century it began to be used as a medicine, and by 1288 it was evidently in general use. Thus the Dominican provincial chapter at Rimini in that year forbade the brethren to possess the "instruments by which they make the water called *aqua vitae*." Arnald de Villanova describes it in 1309–12 and extolls its curative virtues.

But the works attributed to Ramon Lull seem to be the first to treat this *aqua vitae* as an impure form of the quintessence, the active spirit of things. He gives many recipes for making it. Good wine is first distilled, through 'copper side-tubes', then four times redistilled and kept carefully stoppered. Its strength was tested by a quite effective method. Some of the spirit was poured on a pile of sugar or a piece of cloth and set alight. If the spirit contained much water, the cloth or sugar left was so damp by the time the spirit was burned off that it would not catch fire. But if the spirit, when dropped on cloth or sugar and set alight, would ignite them, it was known to be strong enough. The spirit could be further strengthened by distilling it with calcined tartar (mainly anhydrous potassium carbonate) which absorbed some of the water. The result was probably alcohol of 90% to 95% strength. But characteristically, the end product of this clearly described chemical process was regarded only as a 'burning water', *aqua ardens*, and it was not considered to become the real quintessence until it had been 'circulated'.

To this end a large quantity of fermenting matter, such as dung, was heaped up to form a hot-bed, the 'aqua ardens' was placed in a 'pelican' or similar vessel (Fig. 8) and sealed up. The vessel was then half embedded in the dung-bed. The warmth volatilised the alcohol, which condensed on the projecting part of the pelican and ran back again, so setting up a circulation (as in the modern reflux-condenser).

All this is clear; but the result was something that science knows nothing about. The *aqua ardens* was said to separate into two layers, a lower turbid layer, which was to be rejected, and an upper layer, clear and sky-blue, which was the quintessence. When the vessel was opened, a wonderful fragrance exhaled so that birds were attracted to it and people would come crowding into the house. We cannot think, of course, of any possible change that 'circulation' could bring about in alcohol. We must class this part of the story with the rest of the inexplicable marvels of alchemy, yet noting the analogy with the great world in which the original 'argent vive' separated into the blue of heaven and the dull, turbid mass of earth.

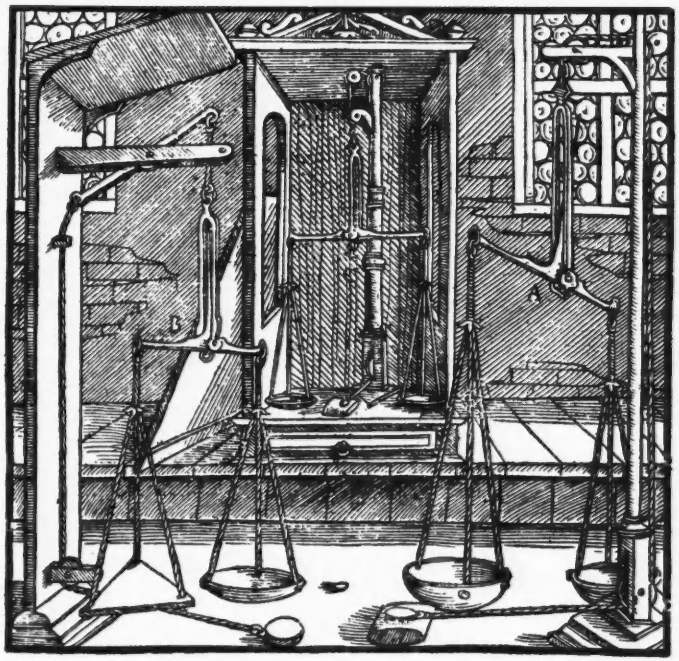


FIG. 9.—Assay-balance from Agricola's *De Re Metallica*, 1556.

The typical still thus became modified in the direction of providing slower heating and better condensation. Few figures of these stills have survived, but we hear of a *serpentinum* which must almost certainly be a worm-condenser, and water-cooling was certainly in use by the 15th century.

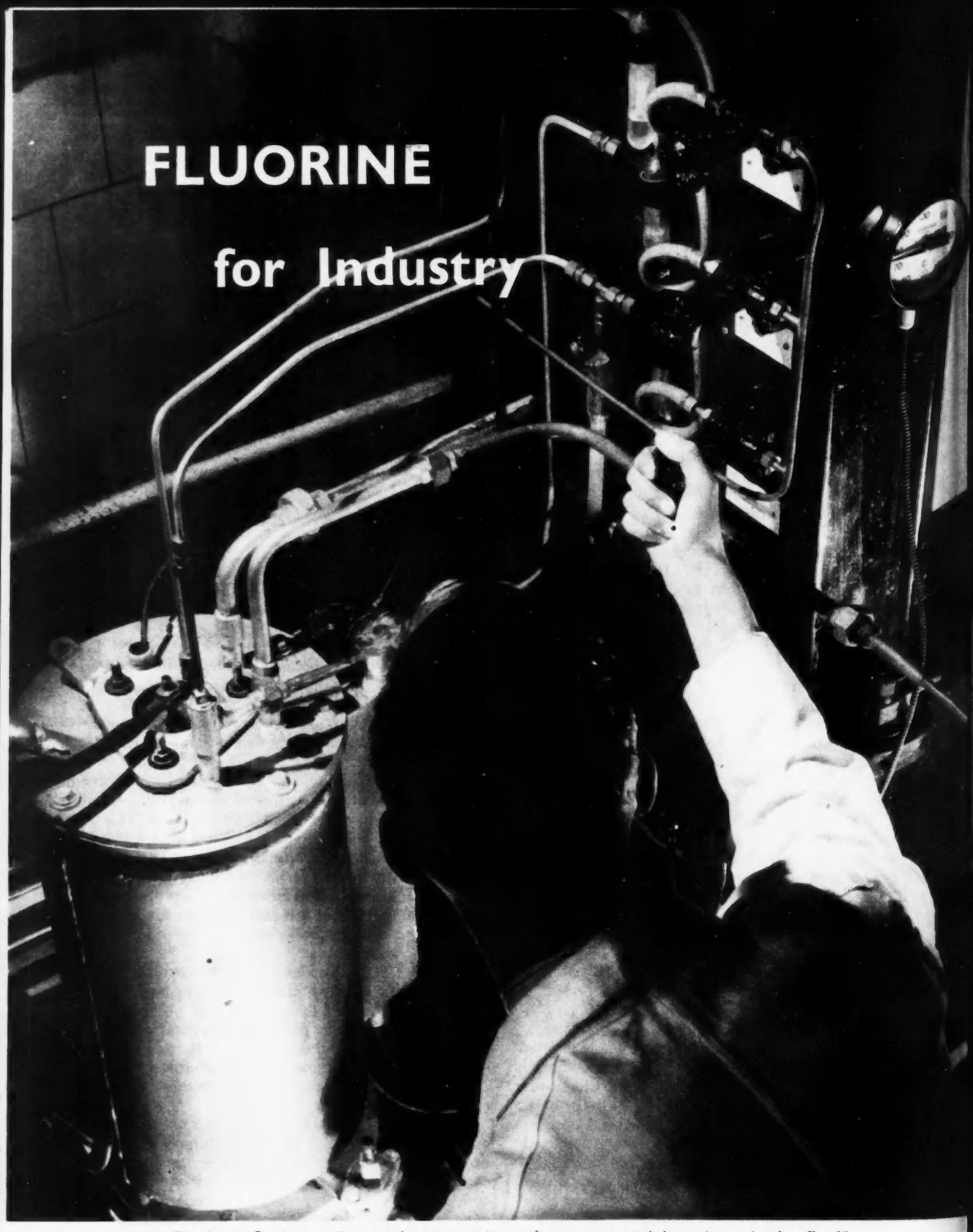
What of the balance? This is the typical instrument of the analyst. We hear of weights of material being specified in pharmacy and alchemy all through the Middle Ages and we can be quite sure that jewellers always had first-class scales. We first hear of special chemical balances with balance-cases in the *Probierbuchlein* about 1510, where the assayer of gold and silver is instructed to get a good Cologne or Nuremberg balance: it is probable that the production of these special balances is a century or so older than this earliest reference to them.

Finally as to medical and surgical instruments, which scarcely call for much consideration. The model in these matters was Albucasis, the Spanish Arab who wrote about A.D. 1000. He illustrates probes, hooks, retractors, scalpels, cupping glasses, the cautery and dental instruments. Other mediaeval surgeons show instruments for dividing and opening the skull, etc. But on the whole these present little evidence of invention.

Thus we may conclude our brief survey of mediaeval scientific instruments. The 13th century, we may think, brought in several remarkable discoveries; the 14th and early 15th were relatively static: in the latter half of the 15th century came the revival of astronomy, and in the 16th, notable development in the instruments connected with astronomy, navigation and surveying. The 17th century brings the full flood of discovery, with the telescope, microscope, thermometer, and very many more.

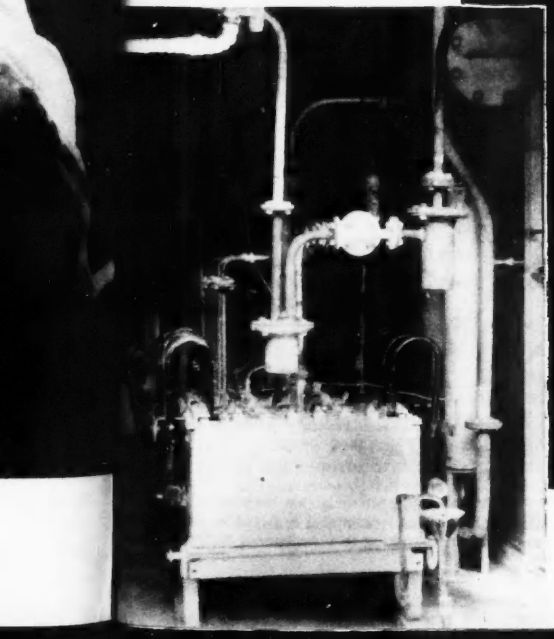
FLUORINE

for Industry



The element fluorine came into prominence during the war because it was needed to make uranium hexafluoride involved in atomic bomb production. Much research and development work on fluorine and its compounds was done in Britain by Imperial Chemical Industries, which now make fluorine in industrial quantities on Merseyside. Another concern, Imperial Smelting Corporation, is also producing fluorine. The first photograph shows an I.C.I. laboratory-scale cell which electrolyses anhydrous hydrofluoric acid and yields 40 grams of fluorine per hour. Such cells are hired out to industrial and university laboratories.

Extremely high temperatures are obtainable if the conventional oxy-acetylene torch is supplied with hydrogen and chlorine trifluoride instead of oxygen and acetylene. *Above* copper being cut by means of such a torch; a clean cut free from oxide results. *Below, right,* the torch being used for welding copper; the process is self-fluxing and there is no trouble from oxidation.



(*Left*)—This is the kind of electrolytic cell used in the production of fluorine on an industrial scale. Larger fluorine-producing cells than this do exist; thus there are in operation 5000 and even 10,000-amp. cells.

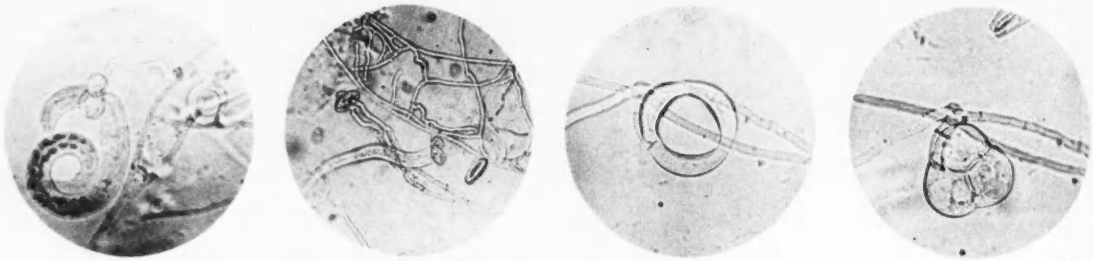


FIG. 1.—These four stills from the film, *Champignons predateurs*, show how the fungus known as *Dactylella* can catch and garrot nematode worms. The photos show the three-celled noose which traps the worms. When a worm touches their inner surface, the cells swell inwards; this effect is demonstrated artificially in the two right-hand pictures, being brought about by the insertion of a fine glass needle into the noose.

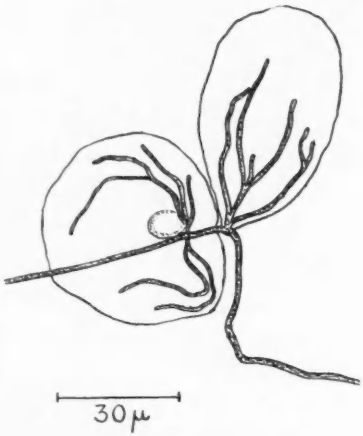


FIG. 2.—*Stylopage rhynchospora*. Part of the mycelium, with two captured Amoebae. The haustorial filaments formed by the fungus are visible inside the amoebae.

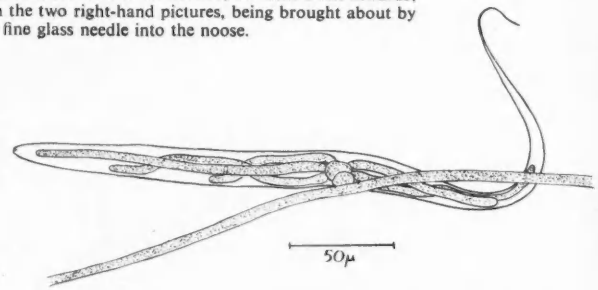


FIG. 3.—*Stylopage hadra*. An eelworm has been captured, and its body is filled with hyphae from the fungus.

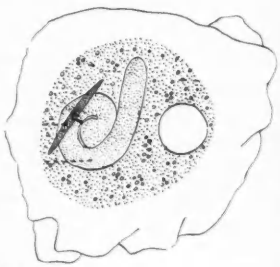


FIG. 5.—*Cochlonema dolichosporum*. An amoeba containing the fungus. The cigar-shaped spore from which the infection started can be seen on the left of the diagram still attached.

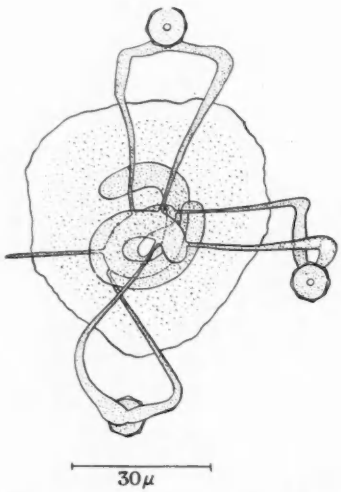


FIG. 4.—*Cochlonema verrucosum*. Sexual reproduction. The amoeba contains two thalli, which are conjugating. Three thick-walled zygospores are being formed. (*Courtesy, Queckett Microscopical Club*).

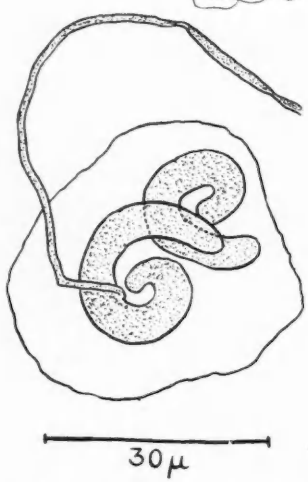


FIG. 6.—*Cochlonema dolichosporum*. The body of an amoeba containing two thalli of the parasite. The free hypha outside the amoeba is constricting to form spores.

Carnivorous Fungi

C. L. DUDDINGTON, M.A., Ph.D., F.L.S.

Most people are familiar with the sundew and the pitcher plants, which capture and digest small insects. The carnivorous habit is not, however, confined to flowering plants, for there are some microscopic fungi which obtain the greater part of the food they need by capturing and consuming minute animals such as eelworms and amoebae. These *predacious fungi*, as they are called, are extremely common in decaying vegetable matter of all kinds, from rotten wood to garden compost, and their name is no exaggeration, for the adaptations that they possess to enable them to capture and hold their living prey often surpass in accuracy and deadliness even the most intricate mechanisms found in the insectivorous flowering plants.

The study of predacious fungi is a relatively new branch of mycology for, although a few species have been known for more than fifty years, it is only during the last decade that their variety and ubiquitous occurrence in nature has been realised. For this we owe a great deal to the work of Drechsler who, since 1935, has described more than a hundred American species, most of which are new to science. It is probable that they are no less common in this country; at present, more than forty species are known to be British, and the list is growing rapidly. Their presence has also been reported from various European countries and other parts of the world. In spite of their wide distribution, however, they are still very little known, even among professional botanists.

For convenience, the predacious fungi may be discussed in three groups:

(*a*) Those attacking Protozoa (tiny one-celled animals inhabiting soil, water, and so on).
(*b*) Those which destroy eelworms (microscopic roundworms, many of which are destructive parasites of garden and crop plants).
(*c*) Other forms, capturing various microscopic animals, especially 'wheel animalcules' (rotifers).

The first group consists mainly of fungi belonging to the Zoopagaceae, a family discovered by Drechsler, and consisting entirely of predacious species. The Zoopagaceae are structurally very simple. The body of the fungus (*mycelium*) consists of tiny threads (*hyphae*), visible only under the microscope. These hyphae are tubular; that is, they are not divided up along their length by transverse partitions into separate cells. The diameter of a hypha is usually only one or two microns*; they are lined with living protoplasm, and contain nuclei and vacuoles filled with fluid.

Stylopage rhynchospora is a typical member of the Zoopagaceae, preying on amoebae. The mycelium consists, as described above, of delicate hyphae which spread over the material on which it is growing—usually decaying vegetable matter of some kind—giving off branches here and there. When a casually passing amoeba happens to touch one of the hyphae, it sticks fast, probably owing to some sticky substance secreted by the fungus. An outgrowth from the hypha then grows into the amoeba and branches to form a system of filaments (***haustoria***) by means of which the fungus absorbs the substance of the amoeba (Fig. 2). The animal is not immediately killed; for a time it continues to make sluggish movements, and the contractile vacuole (the circular vacuole which, by its pulsations, pumps excess water out of the animal) continues to function. As the protoplasm of the animal is progressively absorbed by the fungus, however, these movements gradually cease; the amoeba assumes a more or less rounded shape, and death ensues. The fungus continues to absorb nourishment from its prey until at last only the much-shrivelled ectoplasm (tough outer layer of protoplasm) of the animal is left attached to the hypha.

The fungus reproduces by means of spores. These are tiny bodies which are borne at the ends of special fertile hyphae which stand erect, holding the spores up above the surface of the substratum to a height of about 200μ. A spore formed on the end of a fertile hypha in this way is called a *conidium*, and the hypha bearing it a *conidiophore*. In *Stylopage*, each conidiophore carries a single conidium which, when ripe, is detached from the tip of the conidiophore and, if it falls on suitable material, will germinate and grow into a new mycelium.

About forty species of Zoopagaceae are known which capture microscopic animals by means of sticky hyphae. Most of them prey on amoebae and other Protozoa, but a few of them are large enough to capture and hold eelworms, the animals being caught by contact with a sticky substance on the hyphae in the same way as a bird is caught with bird-lime. Species which capture eelworms are naturally more robust, as these very active creatures fight hard before they succumb. *Stylopage hadra* is an example. Structurally, this fungus resembles *S. rhynchospora*, described above, but its hyphae are usually four or five microns in diameter, and by means of the sticky substance that it secretes it can capture eelworms upwards of half a millimetre long. An eelworm struggles violently when first captured, bending the mycelium this way and that as it tries desperately to get away, but eventually it becomes quiescent and finally dies, and its body is invaded by hyphae from the fungus, which spread throughout the animal and absorb its contents completely (Fig. 3).

Some members of the Zoopagaceae attack amoebae in quite a different way. *Cochlonema dolichosporum*, for instance, captures an amoeba by means of a cigar-shaped, sticky spore which adheres to the surface of the animal on contact. The spore then germinates, sending an outgrowth into the amoeba. This outgrowth develops into a globular structure, which then elongates and becomes sausage-shaped, finally bending in the middle and coiling into a spiral of about one and a half turns (Fig. 5). Such a structure is known as a *thallus*. The thallus grows at the expense of the amoeba which, at first little the worse for the presence of the parasite, finally dies as its protoplasm is absorbed by the fungus. After the death of the host, a hypha grows out from the thallus and ascends more or less

* The micron, unit of microscopical measurement, is equal to one-thousandth of a millimetre, and is usually represented by the Greek letter μ.

vertically into the air; this fertile hypha then becomes constricted at intervals along its length, forming a chain of cigar-shaped spores (Fig. 6). The spore-chains are easily disrupted, the spores being scattered over the surface of the substratum, so that more amoebae are infected.

Besides forming spores, many of the Zoopagaceae undergo a form of sexual reproduction. Two branches from the mycelium—or thallus in forms such as *Cochlonema*—approach one another and fuse at their tips. At or near the point of fusion, a globular spore is formed (Fig. 4); this spore has a thick wall which is ornamented with a number of wart-like outgrowths, and is possibly able to withstand adverse conditions better than the other, thin-walled type of spore. A spore produced in this way is called a *zygospore*, and its formation by members of the Zoopagaceae shows that they belong to the sub-class of fungi known as the Zygomycetes to which group *Mucor*, the common grey or white mould, also belongs. The major groups of fungi are delimited according to the manner of their sexual reproduction; many predacious species, as will be seen later, do not reproduce sexually at all, and so cannot be properly classified.

In our second group of predacious fungi we find those species which prey on eelworms. Here the greatest degree of adaptation to the predacious mode of life is to be found, for many of these eelworm-capturing species possess elaborate mechanisms for the ensnarement of their victims. The eelworm is a vigorous and swiftly moving animal, capable of putting up a formidable struggle for freedom before it is overcome, so that something more than sticky hyphae is needed to catch them in great quantities, especially if the larger species, some of which are a millimetre or more long, are to be captured.

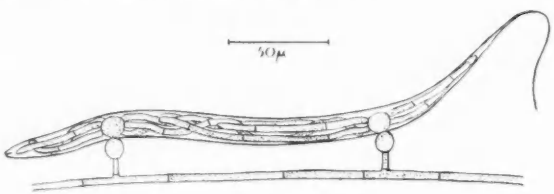


FIG. 7.—*Dactylella ellipsospora*. An eelworm has been captured by means of two of the sticky knobs. The body of the eelworm is filled with hyphae.

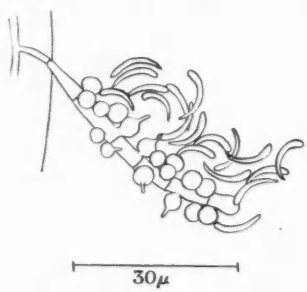


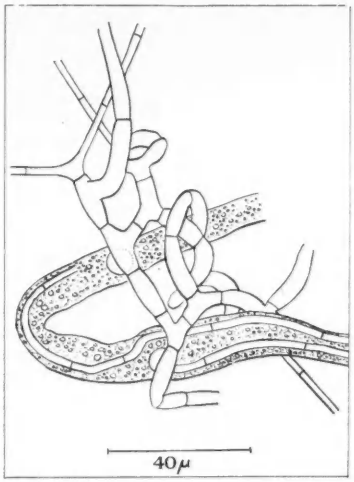
FIG. 8.—*Harposporium anguillulae*. Fertile hypha projecting from the skin of a dead eelworm. Note the strongly curved spores (*Courtesy, Queckett Microscopical Club.*)

One of the commonest of the predacious fungi is *Arthrobotrys oligospora*. This was discovered by Fresenius nearly a hundred years ago, but he did not suspect that it captured eelworms, and it was not until 1888 that Zopf made clear its predacious habit. *A. oligospora* has, attached to its hyphae, complex systems of loops, formed by short branches from the hyphae curling round and fusing with one another, so that three-dimensional networks are formed. These loops are intensely sticky, because of a viscous fluid that is secreted by the fungus on contact with an eelworm, so that eelworms accidentally touching any part of the loops are held fast. From the point at which the eelworm is stuck to the loop, the fungus forms an outgrowth which penetrates the skin of the animal and forms a spherical structure (*infection bulb*) inside it. From this infection bulb, hyphae grow out inside the animal and, filling its dead body, absorb its contents (Fig. 10). The networks not only increase the effective area of the fungus mycelium available for the capture of prey, but many of the loops stand up vertically like croquet hoops from the surface on which the fungus is growing, so that captured eelworms often become entangled in the course of their struggles, thereby lessening their chances of getting away. Fig. 9 shows the surface of a culture in which *Arthrobotrys oligospora* is capturing eelworms, with the carcasses of its victims clearly visible.

Arthrobotrys oligospora reproduces by means of conidia in much the same way as *Stylopage*, described above. The conidiophores are tall, often reaching a height of nearly half a millimetre, and each one bears at its tip a single group of conidia. By carefully picking off the spores with a sterile needle and placing them on a suitable medium, the fungus can be made to grow without eelworms. As long as it is given suitable nourishment, it grows well without an animal diet, but under such conditions it does not form its characteristic loops. As soon as eelworms are added, however, the networks are quickly formed and the destruction of the animals begins. It is not even necessary to add living eelworms; the addition of sterile fluid in which eelworms have been cultivated is sufficient to stimulate the fungus to form its traps. Another feature of these cultures without eelworms is that the fungus produces conidia much more abundantly, and instead of a single head of spores being formed at the tip of the conidiophore, whorls of conidia are formed, often running more than half way down its length (Fig. 11).

The adhesive network is probably the commonest means adopted for capturing eelworms. but it is by no means the only one. Another type of device, also quite common, is shown by *Dactylella ellipsospora*. This fungus has been known, under another name, since 1851, but it was not until 1937 that Drechsler showed that it attacked eelworms. The hyphae of *D. ellipsospora* bears numerous globular knobs, each one attached to the mycelium by a short stalk. The knobs are sticky, and eelworms coming into contact with them are securely held. From the knob an outgrowth penetrates the cuticle of the eelworm and, as in *Arthrobotrys*, gives rise within the animal to an infection bulb from which hyphae grow out and absorb the body-contents of the victim (Fig. 7).

Dactylella ellipsospora reproduces in the same way as *Arthrobotrys*, by means of conidia carried on the ends of tali, erect conidiophores. In *Dactylella*, however, only a



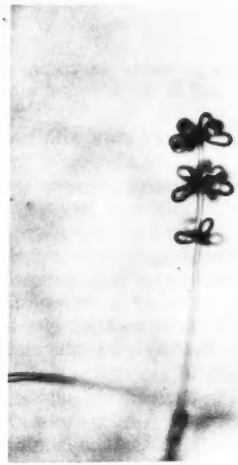


FIG. 9.—*Arthrobotrys oligospora*. (*Left*) Photograph of the surface of a culture, showing the bodies of eelworms captured in the network. FIG. 10.—(*Centre*) An eelworm has been captured by the networks formed by the fungus. FIG. 11.—(*Right*) Photograph of a conidiophore from a pure culture, without eelworms. Multiple whorls of conidia are being formed. (*Courtesy, Queckett Microscopical Club*).

single conidium, made up of several cells, is formed on each conidiophore. *D. ellipsospora* appears to be one of the most widespread of the predacious fungi, having been found in various parts of Europe, in the United States and Hawaii. A number of other fungi use sticky knobs for catching eelworms.

Most remarkable of all the adaptations to the predacious mode of life is that shown by *Dactylella bembicoides*, which possesses nooses by means of which eelworms are 'lassoed' with an efficiency that would be a credit to any cowboy. Each noose is composed of three curved cells, and is attached to the mycelium by a stalk. When the fungus is growing the nooses are held vertically, just at the surface of the substratum, so that wandering eelworms may accidentally pass their heads into the loops. When this happens, the three cells of the loop suddenly and very rapidly swell to more than twice their original diameter, the swelling taking place mainly inwards so that the opening in the loop is practically obliterated. In this way, the eelworm is tightly constricted by the closing of the ring, like a rabbit in a snare, and is thus held beyond any possibility of escape. After the eelworm has become moribund, hyphae from the loop invade its body and consume its contents.

It is by no means certain what stimulus actually produces the reaction of the loops of *D. bembicoides*. Some workers claim that the nooses can be made to close by gently stroking their inner surfaces with a microscopic glass rod, while others have failed to confirm this. Heating appears to cause closure, but this can scarcely be the stimulus operating in nature. Certain chemical substances also seem to be able to close the rings. A close study of the traps of this and other predacious fungi has been made in France by Commandon and de Fonbrune, and by means of a micro-manipulator of special design they were able to record the operation of the eelworm traps on a cinematograph film (Fig. 1).

A rather similar kind of trapping mechanism is found in *Dactylaria candida*, which has stalked rings not unlike those of *Dactylella bembicoides*, excepting that they are not capable of constriction. Eelworms that accidentally pass their anterior ends into the loops become tightly wedged, so that they are unable to get away. Their bodies are then invaded by hyphae from the ring, and their contents are absorbed by the fungus. Sometimes an eelworm manages to tear the loop that is holding it away from its moorings, wriggling away with the ring still encircling its body; if this happens, it is still doomed, for even the detached ring can still penetrate its body and produce hyphae within it.

These three genera, *Arthrobotrys*, *Dactylella* and *Dactylaria*, all reproduce solely by means of asexual conidia, and are not known to undergo any process of sexual reproduction. For this reason, as has been mentioned above, it is not possible to ascertain to which of the principal classes of fungi they really belong. In company with several thousand others whose sexual stages are unknown, they are placed in an artificial group known as the Imperfect Fungi, where they must remain until some investigator discovers their 'perfect' or sexual stage.

Also belonging to the Imperfect Fungi is a group of predators which attack eelworms by means of sticky spores. *Harposporium anguillulae* is an example of this type. This fungus has the distinction of being the first that was ever observed to attack eelworms. The fungus lives entirely within the body of its animal host, the mycelium consisting of a mass of hyphae which, having killed the eelworm, live upon its contents. Only the fertile hyphae grow outside the animal; these are rather short and thick, and they bear at intervals globular spore-producing bodies called *phialides*. Each phialide is provided with a short, narrow neck, at the tip of which a group of spores is formed (Fig. 8). The spores of *H. anguillulae* are very small, and they are easily recognised because they are bent in the form of an arc of a circle. These spores are produced in enormous quantities, and they readily stick to the body of a

passing eelworm and, when they germinate, penetrate its skin and give rise to a new mycelium within its body. *H. anguillulae* is probably the commonest of all the predacious fungi, and is to be found almost wherever free-living eelworms occur.

So far we have dealt only with predacious fungi that live on land. They are also to be found in water, and, although little is known of aquatic species, it seems clear from the work of Peach that they are abundant. An interesting fresh-water species is *Zoophagus insidians*, which is predacious on rotifers, those microscopic organisms with rings of hair-like cilia the waving movement of which gives the appearance of rotating wheels. The hyphae of this species are armed with short, peg-like outgrowths by means of which rotifers are captured, the peg being taken in by the mouth of the animal and giving rise within its body to a complicated tangle of hyphae by which the fungus absorbs nourishment from its victim. *Zoophagus* reproduces by means of *zoospores*—minute one-celled spores that are able to swim by means of a pair of slender tails or *flagella*, the movement of which propels the zoospores through the water.

Not unlike the predacious fungi in many ways are the *entomogenous fungi*, which are parasitic in insects. They are a very varied group, and our knowledge of them is largely due to Petch. Two of these fungi may be familiar to many readers. *Cordyceps* attacks various insects, eventually forming within the body of the host a solid mass of hyphae (*sclerotium*) which completely fills it. From the sclerotium grow out club-shaped structures on which the spores are formed (Fig. 12). Also fairly common is *Empusa*, which destroys house-flies. The fungus inside the host consists of separate, short segments called *hyphal bodies*. After the death of the fly, long conidiophores grow from these out through the integument of the host, and on their tips are formed conidia which, when ripe, are shot off violently. In the autumn a dead fly can often be found sticking to a window pane, surrounded by a halo of discharged conidia.

FIG. 12.—*Cordyceps militaris* on a caterpillar. (*After Tulasne.*)

The ecology of predacious fungi, that is, their relations with their environment, is a fascinating subject about which very little is known. It has already been said that predacious fungi are common in decaying vegetable matter of all kinds; they are also to be found in the dung of animals, in the soil, and particularly in mosses. The last habitat is, surprisingly enough, very rich in predacious fungi, which feed on the nematodes and Protozoa harboured by the moss. Even the tiny moss that grows between the paving stones in the streets of Greater London may be a source of predacious fungi; in one small collection of moss from the pavement outside my own house, I recently found no less than four different species, one of which proved to be new to science. The reason for this connexion between predacious fungi and mosses is not known, but it is not improbable that the moisture held by the moss is an important factor. An even stranger habitat is recorded by Sadebeck, who found a species of *Pythium* attacking the Vinegar Eelworm in vats of vinegar.

The part played by predacious fungi in helping to maintain the 'balance of Nature' is probably an important one, though we have no direct evidence on this point. Since they are both widespread and destructive, it would be surprising if they did not assist under natural conditions in keeping down the numbers of microscopic animals, and particularly eelworms, wherever they occur. Precise information is difficult to obtain, and much work will have to be done on the ecology of predacious fungi before we are able to assess their importance with any accuracy. The eelworm is a very destructive parasite of many crop plants, and as yet no universally effective means for its control has been found. If it could be made possible to use these fungi deliberately against the eelworm, the economic value of the technique might be very great.

The idea of biological control of eelworms by means of predacious fungi is not a new one. Linford and his co-workers in Hawaii have attempted to use them against the eelworm causing root-knot disease in pineapples but, though they have claimed a certain measure of success in their experiments, their results are inconclusive, and the means they adopted could almost certainly be bettered. Attempts have also been made in France to find a means of using them to combat eelworms parasitic in domestic animals. One thing is certain; any economic development of the predacious fungi for the control of eelworms will need to be based on a sound understanding of the fungi themselves, and until this understanding has been gained, no such development is likely to succeed.

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Research in Ageing

ALEX COMFORT, M.A. M.B., Ph.D., D.C.H.

THE expectation of life in Britain has increased steadily over the last hundred years. This increase is chiefly due to the fact that fewer people, and particularly fewer infants, children, and young adults, die prematurely from infective disease. An ancient Roman had an expectation of perhaps 20 years at birth, compared with over 60 in Britain today. The net effect of medical research so far, however, has been to prevent early death rather than to prolong the life span of those who reach middle age. It has been optimistically said that the next ten years may see the retreat of the infectious diseases converted into a rout—an important result of this process is already apparent in the increased part which degenerations and structural defects due to age are playing in medical practice. If at any time in the near future malignant disease, itself a condition chiefly affecting older adults, should succumb to any specific treatment, death due to age changes in the heart, kidneys, blood-vessels and nervous system would account for all but a very small part of the bill of mortality.

This prospect, and the change in the age-composition of the British public, is bound to divert medical research to cope with the degenerative diseases. It is also becoming plain to workers in this field that so far no fundamental understanding of the significance and biology of ageing has been reached. Some such understanding is becoming urgent, as the counterpart to the advances in fundamental knowledge of development, resistance to infection, and bacterial and physiological chemistry which provided the background of the control of infectious disease. Metchnikoff's remark in 1914 that "Science knows very little about old age and death" is equally true today.

The Ageing Process

Changes comparable to those associated with human and mammalian old age are found in all animals which do not reproduce by simple division. Nineteenth-century biologists spoke of the mortality of the individual in contrast with the immortality of germ plasm. In many insects, death follows rapidly upon reproduction: in others, such as the bee, the sexually mature female lives far longer than the non-reproductive worker. Most of the larger organisms, however, have a more or less protracted reproductive life which merges into senescence and death.

Extensive work has been done on the ageing of unicellular organisms, especially ciliates. Woodruff in America cultivated *Paramoecium*, which is an organism consisting of a single cell, for more than 8000 generations without any sign of senescence in the stock. In the simple many-celled animals known as planarians (which are aquatic flatworms) individual life is limited, but the animal has the power of 'de-growing'; in response to an unfavourable environment it shrinks in size, and appears thereby to acquire some of the metabolic characteristics of youth. By treatment with dilute hydrocyanic acid, the individual can be 'de-grown' in this manner a number of times, and perhaps indefinitely.

If unicellular organisms such as *Amoeba* or *Paramoecium* are grown in a closed volume of fluid, the growth-curve of the population closely copies that of a single multicellular organism. It rises steeply, and then levels out, and after a varying period the culture 'ages' and dies. In most of the forms which have been studied, this effect is not due to utilisation of all available food, but to the appearance in the medium of toxic substances produced in the process of growth. We shall return to this conception later.

Many older biologists regarded ageing as an inherent property of all cells in multicellular organisms which are not directly concerned in reproduction. In this view, the individual body-cells should contain a time-limiting mechanism which runs down after a predetermined period. A mechanism of this kind is known to limit the life of human red blood cells, which contain no nucleus, but the work of Prof. Alexis Carrel and others during the early years of this century made it clear that individual body cells *per se* are not limited in this way. The cultivation of chicken heart-muscle cells which was maintained for twenty years in repeated subculture, growing all the while, is well-known. The evidence from tissue culture makes it clear that ageing, except in cells such as those of the brain and spinal cord (which cannot divide once they have become functional), is a property of the whole organism, not of the isolated cell.

This conclusion leads us to look for causes of ageing in the internal environment, rather than in the cell itself. An immediate difficulty at this point lies in the fact that the age process is not uniform throughout the organism. The blood vessels in man begin to show age changes in the seventh year of life, with the appearance of fat deposits in the wall of the aorta (the main artery by which blood leaves the heart); other kinds of cells, such as those of cartilage, change little in form during life, and may even survive the death of the organism by many hours. The process involves a mass of subsidiary causes and effects, and it is almost invariably complicated by disease. Age changes which affect blood vessels or the endocrine glands, for example, produce widespread effects out of all proportion to their extent. Thus senile change affecting part of the wall of the coronary artery, which supplies the blood muscle of the heart's wall, is an extremely common cause of sudden death.

It is with key changes of this type, rather than with the fundamental biology of ageing, that medical research is mainly occupied, since by their control it should be possible to extend the healthy life-span very considerably. Early attempts to influence the course of the age process itself were almost all directed at supposed endocrine deficiencies, and the discovery of hormones led to a very large number of ill-judged claims that active life in man could be prolonged by means of gland extracts, implants, and similar measures. Steinach's operations, and Voronoff's 'monkey glands', enjoyed a brief, though considerable, vogue. Quite a literature on these techniques accumulated; there are still some proponents of these

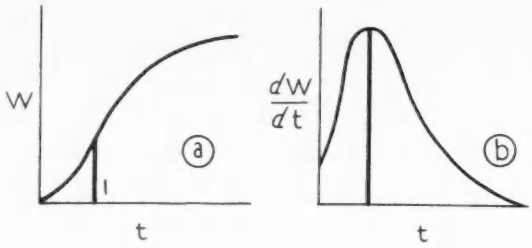

FIG. 1.—Typical S-shaped growth curve (*a*) and the curve of growth rate (*b*). Notice how at the major inflection, which is marked, the gain of weight becomes slower; *i.e.* the growth rate is falling as is clear in (*b*).

techniques and the biologist who works on age problems finds himself continually obliged to repeat that attempts at 'rejuvenation' and the search for elixirs of life are not part of his programme. Some part of the neglect of this branch of biology is due to the disrepute brought on it by endocrine alchemists. It can be said with confidence that the known sex hormones play only a secondary part in the development of senility, and there is no evidence that their administration can prevent its development in any organism. The role of the pituitary group of hormones is less clear. They occupy a key position in relationship to the central nervous system, which, as has been said, is particularly liable to structural changes because it is not renewed during life. Disease of the pituitary has been known to produce states simulating old age in young adults, but total removal of the gland is not followed by senescence in animals, and there is no ground for regarding deficiency of any one hormone as the main mechanism of secondary age changes.

Some light is shed on the primary character of ageing in cells by a comparative study of longevity, and by the study of inanimate structures. Colloids of all kinds undergo physical changes with the passing of time, and changes in elasticity of the skin, skeleton, and connective tissues can be observed in old animals. Similar changes in cell-walls or intercellular substance may play a part in fixing the life span of an organism. *Heredity* in man and in animals plays a predominant part in determining how long an individual can live if he escapes all accidents of his environment. Longevity in animals bears a definite but not an invariable relation to *size*—thus it is generally true to say that animals which grow rapidly, have a high rate of metabolism and are of small size have the shortest lives.

The painstaking work of Flower has shown that most of the stories of great longevity in animals belongs to fiction rather than zoology. In spite of tradition, there is no reliable evidence that any fish reaches an age much greater than 50 years. A specimen of Marion's Tortoise, now extinct, which reached an age of between 150 and 200 years probably holds the record for the longest-lived vertebrate. Several of the larger birds may live for fifty years: the only mammals which are known to exceed this age are man, the horse, and the Asiatic elephant. (Fig. 2).

While naturalists have exaggerated the ages of animals, centenarian human beings have frequently overstated their own. A careful review of recorded super-centenarians carried out by Dr. V. Korenchevsky at Oxford fixes 112 or 113 years as the greatest age which can be taken as proven by records in this country. The celebrated Thomas Parr, who was examined by Harvey, and died at a reputed age of 152, may have been the victim of his own failing memory or of the credulity of scientists. Man is in any case the most favoured of the active organisms as far as long life is concerned, though his span is insignificant compared with that of the giant redwood tree which may live 4000 years, or the swamp cypress and the yew which may live for more than 1000 years. At the lower limit for vertebrates come the voles, bats, and smaller birds, which live less than five years.

Ageing and Growth

Attempts to relate body weight or length of gestation to longevity have failed, but there is abundant evidence to relate it to the rate and persistence of growth. Carrel's work showed that cells which continue in active growth do not age. Man not only lives longer than most organisms, but devotes a greater proportion of his life to the task of reaching maturity.

An attempt was made by Minot, early in the century, to integrate the processes of growth and of senescence in a uniform theory. His work has been subsequently extended and modified. As in the case of cultures of unicellular organisms, it has been suggested that the process of ageing is an expression of the activity of the same factors which cause growth to cease after a limiting size has been reached. The growth curves obtained by plotting weight against time has an almost identical shape in organisms as unlike as children, pumpkins, bacterial populations treated as an organism, and rats (Fig. 1). Before a critical point (puberty, maturity), the process of growth goes on at compound interest; after that point it declines at negative compound interest. This tendency to attain a limiting size appears to be closely connected with the cause of ageing. Several attempts have been made to discover organisms which have no limiting size, to ascertain if they are potentially immortal. The nearest approach to this state seems to be reached in the giant redwood tree, whose size is probably limited only by mechanical considerations; but claims that certain fish and crabs are capable, in theory, of continuing to grow for ever do not seem to be supported by facts.

It can be said that in all known examples the growth curve of many-celled animals is S-shaped, and that the decline in growth rate is parallelled by the onset of some senile changes.

The most important experimental demonstration of a relationship between ageing and growth rate comes from the work of McCay on rats. The normal expectation of life in the rat is about 600 days. When batches of rats were placed at weaning on a diet which contained adequate vitamins, minerals and proteins, but insufficient calories to permit growth, they reached a stationary state in which they could be kept alive for periods up to 1000 days. They were then transferred to a diet adequate in calories and although they had already greatly exceeded the normal span, began to grow, the oldest dying at ages approaching 1400 days. "In general," says McCay, "the retarded rat remains active and appears young whatever its age. It is very alert, but tends to go blind in the second and third

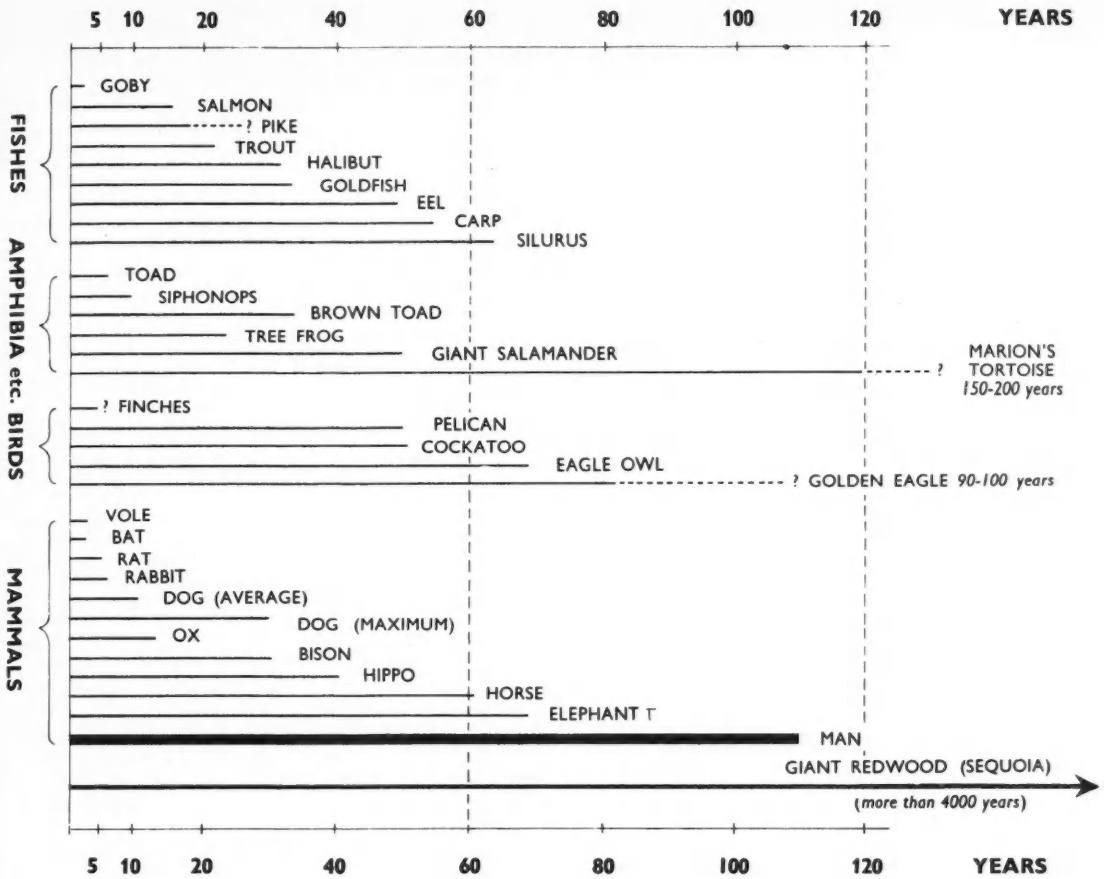

FIG. 2.—The relative longevity of organisms (based on data from Todd, in Cowdry's *Problems of Ageing*).

year of life. Its pulse rate is about 100 below normal." Similar lengthening of life by retardation of growth has been recorded in fishes, fruitflies (*Drosophila*), the water flea called *Daphnia*, and other organisms.

A hypothesis which has always been canvassed as an explanation of ageing is that the change in cell behaviour is the result of the action of a substance or substances produced during the life of the organism which gradually impair the power of cells to repair damage due to wear and tear. One celebrated, and exploded, form of this theory is Metchnikoff's view that poisons due to bacteria in the gut are responsible. But we can possibly relate a 'toxic' theory of age to the observations on growth-rate and growth-cessation. Carrel and Ebeling showed as far back as 1921 that the blood serum of animals contains growth-inhibiting substances which increase in concentration with increasing age, and the power of wound repair falls off in a similar manner. At the same time experimental embryology has shown that the differentiation and regeneration of organs and structures are under the control of a complex interplay of chemical substances known as 'organisers'. Secondary organising substances such as the sex hormones, which have been prepared in a pure state, exert strong and selective control over the multiplication and growth-capacity of cells. In fact, inspection of the growth curve suggests very strongly that its cessation is an example of 'negative feedback', of the type which is becoming increasingly familiar in physiology, and that there are specific mechanisms which limit growth at a fixed point. The tissue-culture experiments of Prof. Gaillard and Prof. Duyff at Leiden have further suggested that certain tissues of the body may exert a mutual control over one another by way of the substances they produce during growth. A standing difficulty of tissue cultures grown in the normal manner, in a medium containing embryo juice, is that they tend to revert to primitive form, and, in the case of specialised cells, to become non-functioning. A particularly interesting series of experiments reported by Gaillard, using pieces of tissue from the parathyroid gland, arose from his attempts to maintain a stock of functioning gland tissue for implantation into patients whose parathyroids were defective. Gaillard has claimed that cultures of these tissues can be

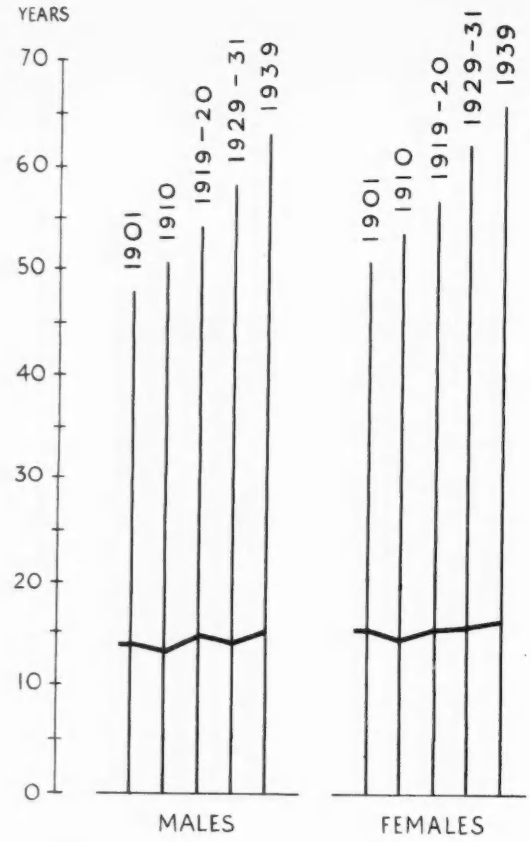

FIG. 3.—Expectation of life for white males and females in the United States, 1901–1939 at birth (upright lines) and at 60 years (lower graph). The decrease in mortality is almost wholly in the earlier decades of life, the expectation at 60 remaining substantially constant. (*After Dublin.*)

maintained in the adult and functioning state by growing them in media derived from hosts of increasing age—an extension of these findings to cover the effect of extracts from senescent hosts would be of great interest. It may also be possible through work of this kind to fractionate out some of the 'organisers' themselves as concentrated extracts, and ultimately to identify them chemically. Further work on these lines, and fractionation of the inhibiting substances, if their existence is confirmed, are among the studies which we may expect to see carried out in the near future. The form of any organism can be regarded as an equilibrium between the growth-tendency of its cells and factors which restrain it. It is possible that studies of this type may link up not only with cancer research (since cancer is in essence the 'escape' of cells from mechanisms which normally regulate tissue organisation), but also with research into the chemistry of hormones.

The conclusion of most tissue-culture studies is that cells in aged animals have not lost the capacity for renewal, but that they are held in check by factors, possibly chemical, in the organisms as a whole. In isolation they grow, but take longer to begin doing so than do younger tissues.

Another important aspect of longevity is that it is strongly hereditary, the expectation of life in individuals of long-lived stocks being significantly above average. How far such longevity can be measured by selective breeding in animals is not yet known, largely owing to the difficulties of selecting for an attribute which appears after the close of the reproductive period. What the genetic make-up determines is not the actual but the potential life span, the age which is in fact reached being a function of the environmental stresses which the individual encounters. It remains true, however, that the best recipe for long life is to select long-lived ancestors.

The study of the actual mechanisms involved in the inheritance of longevity, and along other equally productive lines, has hardly begun. High levels of activity have often been incriminated as a cause of ageing, especially to explain the greater longevity of women, on the assumption not that women do less and therefore survive longer, but that they have a better-damped reaction to stress. From the nutritional side, much literature exists on the best vitamin intake for longevity in various organisms. In the honey bee, larval diet determines not only length of life but also affects sexual development. Royal jelly, on which the larvae that grow into queens are fed, is a particularly rich source of the vitamin pantothenic acid, and this association has led to several attempts to demonstrate a protective action in other organisms, mostly with inconclusive results.

The gerontobiologist usually finds himself in possession of one of those enormous and heterogeneous card indexes characteristic of a subject in which no clear lead has yet appeared. In spite of its great interest, we need to recognise that the field of research into ageing presents quite exceptional practical difficulties, and these are responsible for the rather desultory character of much of the work undertaken in the past.

Apart from the extreme difficulty of separating 'normal' old age (the processes associated solely with the passage of time and its reaction on the organism) from the ills associated with old age, practical difficulties arise at many points which might be overcome if there were a wider appreciation of the importance of the subject among scientists. Old animals are particularly hard to get, and often require special and costly attention. The case for a central supply of material is overwhelming, but is likely to have to wait for a wider awakening of interest in the biology of age. There needs to be discovered a means by which senescence in convenient animals could be effectively speeded-up; this would provide a source of material analogous to that which cancer research draws from chemically induced and transplanted tumours. Whether such a discovery is at all likely cannot at present be predicted. The time-scale of human life limits many kinds of study to small animals whose life and growth cycles are unlike our own. The most abundant aged animal is undoubtedly man, but co-ordination between clinicians and biologists for the observation of aged patients is in its infancy, though it has already made considerable strides. The work of several gerontological organisations in Europe and America, and the recent support given to research in ageing by the Nuffield Foundation in this country, may very well prove the starting points of a general advance in knowledge.

Prof. P. B. Medawar has written: "If a physiologist were

to study the problem of ageing from scratch, he would not even begin to try to modify the time-course of senescence by the administration of vitamins or elixirs compounded by the juices of glands. He would first of all try to piece together a full empirical description of the phenomenon of ageing as it is reflected in structural changes of tissues and cells. . . . Only scraps of such information are now available."

The most urgent need in the biology of ageing is for the performance of properly-designed critical experiments to clear up the fundamentals of the nature of the ageing process, its relation to secondary effects such as the cessation of sexual function, and its relation to growth and to tissue organisation. This work is an essential accompaniment to medical studies on the specific pathology of age. If the biologist is asked whether human ageing is ever likely to be controllable, in part or in whole, he can at present only answer that until the nature of the processes involved is known, no predictions can be made. From the social side, however, it must be realised that the increase in longevity which would result from even a limited measure of control—from the development of an effective means of preventing the deterioration of blood vessels, for example —would have important and possibly catastrophic effects in a world which is rapidly becoming over-populated. Even a limited advance of this type might produce a greater revolution in social patterns than any number of atomic bombs. At the present time our society is finding difficulty in coping with the increased numbers of people who are reaching later life, without any dramatic increase in the final age which such people reach, but highly important work is in progress in the social medicine, psychology, and rehabilitation of aged people.

Prof. F. C. Bartlett and his co-workers at Cambridge have recently undertaken a widespread survey of the physiological traits and aptitudes of the old. By means of performance tests, they have been able to follow the decline in learning-power, rapidity of thought and action, and originality which occur with age. These disabilities are outweighed from the occupational point of view by increasing capacity to take pains and by experience—the work done by Goethe in his later years, and by many other aged artists and scientists, indicates that the supposed loss of efficiency and originality with age is a variable process, depending on personality and upon the type of task. More interesting, perhaps, is Bartlett's finding that the characteristic psychological changes begin not at the age of retirement but during the middle twenties, and are well advanced by the time that the prime of life is reached.

An equally important study by Dr. J. H. Sheldon at Wolverhampton has been directed to finding out how the old live, and what disabilities they experience. This survey showed a high incidence of minor, remediable factors such as bad sight and hearing, inability to climb stairs, dizziness on looking up, which can circumscribe and effectively imprison an old person who is otherwise capable of living a happy and useful life under suitable conditions.

A civilised recognition of the claims and potentialities of aged people should preferably precede any attempts to increase the life span. In this field we may run that risk of allowing biology to outstrip our social organisation, a state of affairs which has already confronted us with a falling death rate in overcrowded countries, and produced a situation which our political and economic system is unready to meet. Since medical science cannot be slowed down by any legitimate means, a commensurate speeding-up in the growth of our social sciences and their application to society becomes more urgent than ever.

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The Supply of Scientists

A SERIES of reports on present and future supply and demand for various types of scientists and technical experts are being published by H.M. Stationery Office. So far the reports published cover chemistry, physics, geology and electrical engineering. The reports were prepared by specialist sub-committees under the general direction of the Technical Personnel Committee of the Ministry of Labour, and will be of great interest to science masters and others who have to advise students as to which scientific and technical subjects offer good 'career prospects'.

During the next few years there may be a shortage of physicists, but after 1952 there is a possibility of more physicists being trained than can afterwards be employed. This is the general conclusion reached by the Physicists' Sub-committee which estimated that the highest employment figure would be reached between 1950 and 1955 and that after 1955 the demand for physicists would decrease. In general industry it is estimated that twice as many physicists will be employed in 1950 as in 1945 but that future requirements will vary from industry to industry. In the electrical and radio industries, for instance, employment of physicists will probably double in the next few years; in the scientific instrument industry, on the other hand, no great increase in demand is foreseen.

In the Research Association, where the annual recruitment is about 30 physicists, this figure is likely to drop to about 20 from 1956 onwards. In government departments with a present employment of approximately 175, only 50 are likely to be wanted after 1951. On university staffs about 20 physicists are employed annually and this figure is likely to remain constant, but in the teaching profession, on the other hand, the demand is again expected to drop after about 1956.

The report points out that in assessing these figures not only the quantity but the quality of trained physicists must be remembered. Very often graduates who fail to achieve the highest academic honours are still highly capable of filling a post satisfactorily, and the sub-committee deplores the present tendency of employees to insist on first- or second-class honours degrees.

The immediate demand for geologists far exceeds the supply and in certain undertakings such as those connected with colonial survey work and mining geology this demand is likely to continue. The sub-committee who investigated this field states that before the war only about 20 geologists graduated from the universities each year. This number is expected to be greater in the next few years.

In the field of chemistry the demand for trained chemists seems likely to exceed the supply for the next five years. Over the next five years the number of qualified chemists leaving universities, schools of chemistry, and so on, will be about 7750, as against an estimated demand from industry, teaching, and public service for 9650. It is emphasised that there is a place within the chemical industry for the man with academic qualifications other than a first or second class honours degree. One matter of concern to the Chemistry's Sub-committee making the report is the alarming shortage of teachers of chemistry. Another cause of concern is the shortage of chemical analysts.

A Most Remarkable Fly

In the family Cuterebridae of the two-winged flies (Diptera), there is an insect, *Dermatobia hominis L.* of great importance to cattle.*

As to its distribution, it is known to occur throughout the whole of Central America, and is very widespread. Its distribution seems to indicate that it prefers humid and mountainous regions; it is a woodland species and the adult is usually difficult to find.

The usual method of reproduction is very peculiar. In Costa Rica it is common to find its egg-masses attached to stable-flies (*Stomoxys calcitrans L.*) or on the mosquito *Psorophoro lutzi*. The adult is vigorous and agile, which enables the female to catch the stable-fly or mosquito which is weaker than it, to overpower it and to attach a batch of eggs on one side or other of the body of the captive. The eggs are covered by a gummy substance which fixes them to the body of the fly or mosquito carrier, and which hardens in the air. Stable-flies have been found with as many as 45 eggs adhering to them. On occasions when the female does not find a carrier, it is able to lay its eggs on plant foliage. The part of the host preferred for oviposition is the region between the thorax and abdomen, under the wings. The eggs are elliptical and of a creamy-white colour, and have an operculum through which the larva emerges. The larva begins its development as soon as the egg is placed on the intermediate host, and takes advantage of the opportunity provided by the blood-sucking habit of this intermediate host, by passing to the final host when the vector alights upon it. The parasite is able to make use of the puncture made by the vector in order to suck blood, and enters the body of the animal in this manner. In the absence of such a puncture, it is able to enter through the pores of the skin, or through the bases of the hairs. It is attracted, while still developing inside the egg by the warmth or sweat of the animal, and in cases when it is induced to hatch, but the host is unsuitable (e.g. a horse) it can withdraw into the eggshell again until an animal which attracts it is found, or at least for a period up to about one day.

The larva seems to prefer certain parts of the body, such as the back and the forelimbs; in the latter, it prefers the posterior part, between the elbow and the pastern where it is more protected. It also appears to select the region of the back of the neck.

Having introduced itself beneath the skin, the larva produces a painful swelling which secretes a blood-stained serum, and which has a small hole communicating with the exterior. Within this it completes its development, then emerges from the animal, and burrows into the soil, where it pupates, and finally reaches the adult state.

The damage caused by these parasitic animals results in the deterioration of the skin, because where the wound has healed a callus is formed, and in the curing of the hide this part is consequently weaker and very liable to tear; the living animal has a repulsive appearance, its expression is uneasy and pathetic, it becomes thin, and if a milking cow, its production falls. Furthermore, the wounds sometimes serve as centres for secondary infections.

This insect is found attacking various species of animals: the wild species as much as the domestic ones. Cattle, dogs, deer, are attacked, horses and pigs but rarely. Man is also attacked: frequently in some districts.

Various methods of control have been tried in Costa Rica, all of them to some extent satisfactory but not completely so, some being almost ineffective. The system now in use, based on 'Chlordane', has proved to be the most effective. It is used in the form of high-pressure sprays (250 lb. sq. in.) or in cattle dips. In either case, an oil emulsion diluted to 0·25% concentration in water, is used. The treatments are made every 22 days, but the intervening periods may be extended, until they are carried out monthly. When 50% wettable powder is used, the concentration for the dip must be 2% to 3%. The method has to be combined with the cleaning up of stables, by which means the vectors of the parasite tend to be eliminated.

E. Morales M.

* In Costa Rica, it is commonly known by two vernacular names; 'Torsalo' or 'Torzalo' in the Meseta Central; 'Gusano de Monte' in the province of Guanacaste. Its current nomenclature also varies in the different Latin-American countries; for example, in Brazil it is called 'ver macaque'; other countries refer to it as 'colmoyote'; 'gusano macaco'; 'cormollote', 'nuche', 'gusano de monte', 'gusano de zancudo', 'gusano macao', 'ver moyocuil', 'hura', 'ura', 'torcel', 'berne', and so on.

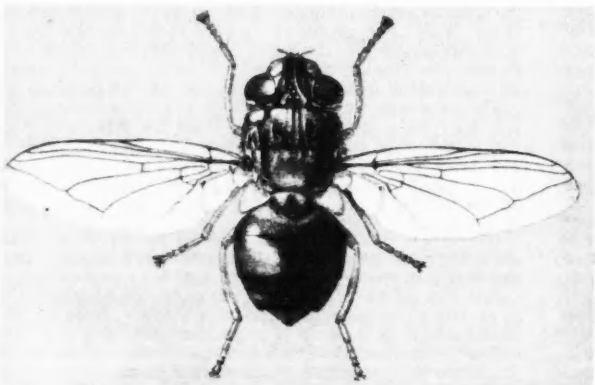


Fig. 1.—The fly, *Dermatobia hominis* × 3.

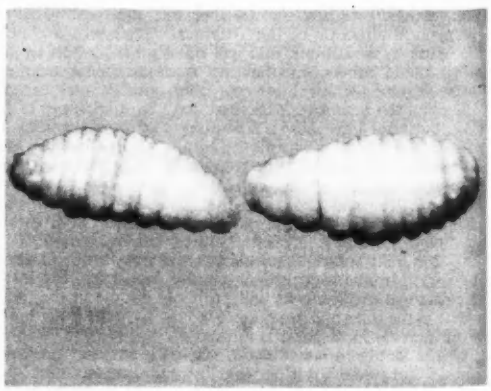


Fig. 2.—Final larval stage. Each larva is about 2 cm. long.

Far and Near

The Dineutron Detected?

THE existence of a new particle—the dineutron, or double neutron—is now slightly less hypothetical as a result of research carried out at the Los Alamos Laboratory of the U.S. Atomic Energy Commission, briefly reported in *Physics Today* (July 1950). This journal says the search for the dineutron has been almost uniformly unrewarding, but preliminary results of a set of experiments conducted at the Los Alamos Scientific Laboratory give hope that the dineutron has in fact been observed. At the Washington meeting of the American Physical Society, Harold Agnew, representing a Los Alamos research group headed by Richard Taschek, described a study of the triton-triton reaction in which the Los Alamos two and one-half million volt electrostatic generator was used to accelerate tritons. The emission of alpha particles in the reaction provides the clue for detecting dineutrons, the maximum energy for the alpha particles for any given angle being obtained whenever two neutrons come off in the same direction, either as separate particles or as a dineutron. In the latter case, according to the Los Alamos workers, a group of alpha particles may be expected which should vary with angle in a predictable manner. The experiments provided some evidence for such a group.

In Great Britain, scientists at Harwell were reported in 1949 to have unsuccessfully attempted to find evidence for the dineutron in an experiment in which an isotope of bismuth was exposed to the neutron flux of the Harwell pile. The characteristic disintegration products that might have been expected if dineutrons were present were not detected.

Television Freaks

AMERICAN television transmissions covering bands of frequencies from 54 to 216 megacycles in twelve channels, often present problems to the radio serviceman which are rarely met in this country. Many of these problems are concerned with freak reception or absence of reception due to surrounding buildings or masses of metal in the neighbourhood of the receiver.

Writing in *Radio-Electronics*, Martin Clifford gives some examples of puzzling cases: one viewer in Manhattan could receive every channel except No. 2, which only became tunable when a heavy vase was stood on the receiver; the base of the vase contained a lead ring and this presumably was acting as a resonant re-radiator. In another receiver, Channel 4 went off the air apparently at 4 p.m. each day, a time which coincided with the pulling up of a metal venetian blind in the house opposite. In this case also the blind was presumably acting as a reflector.

One example of variable reception has been found to be connected with the movement of the local gasometer, and another with the mooring of a ship at the local pier.

Troubles of this nature provide an argument for the transmission of television programmes from aircraft above the earth's surface, which would provide actual line-of-sight signal range of 200 miles or more.

In Britain, viewers on the south coast report frequent reception of the programme from the Eiffel Tower station, although clear resolution is not possible on ordinary receivers owing to differences in the standards of transmission. The weather intervening between Alexander Palace and receivers on the 'fringe area' has a marked effect on the quality and signal strength of the London programme; usually outlying viewers hope for a foggy night in London!

Night Sky in September

The Moon—New moon occurs on September 12d 03h 29m, U.T., and full moon on September 26d 04h 21m. The following conjunctions with the moon take place:

September				
10d 20h	Venus in conjunction with the moon	Venus	1°	S.
16d 17h	Mars ,,	Mars	3°	N.
23d 13h	Jupiter ,,	Jupiter	1°	N.

In addition to these conjunctions with the moon, the following conjunctions also take place:

September				
9d 04h	Venus in conjunction with Regulus	Venus	0·7°	N.
24d 03h	Mercury in conjunction with Venus	Mercury	2·6°	S.

The Planets.—Mercury is in inferior conjunction on September 17 and is not well placed for observation until the end of the month when it rises about 1h 35m before the sun and may just be seen as a morning star but will be a difficult object. Venus, a morning star, rises at 3h 25m and 4h 05m on September 1 and 15, respectively and an hour before sunrise at the end of the month, but about this time is drawing too close to the sun for favourable observation. Mars sets at 20h 35m, 20h, and 19h 30m on September 1, 15, and 30, respectively: about September 10 the planet is close to the star ι Librae, Jupiter rises in the early morning hours and is visible throughout the night in the constellation of Aquarius. Saturn in conjunction with the sun on September 16 is unfavourably placed for observation.

An eclipse of the sun on September 12 is invisible in the British Isles. The total eclipse of the moon on September 26 is only partly visible in this country. The eclipse begins when the moon enters the penumbra at 1h 20m and ends when it leaves the penumbra at 7h 13·5m. On September 26 the moon sets at 6h 02m in the latitude of Greenwich so that this time nothing of the eclipse can be seen in this country.

Atomic A.R.P.

THE first manual on atomic A.R.P. has appeared; this was published on July 26 by H.M. Stationery Office, price 2*s*. Its full title is *Atomic Warfare*, and it is the sixth pamphlet in Vol. 2 of the "Manual of Basic Training" for Civil Defence.

It describes the hazards of atomic warfare and outlines the steps that can be taken to reduce the dangerous effects of atomic bombing. It takes a very different line from the A.Sc.W. pamphlet reviewed elsewhere in this issue; there seems to be only one point on which the two agree and that is that civil defence measures could be decisive to survival in event of another war in which a few atomic bombs were dropped. Hence A.R.P. designed to meet the special hazards of atomic war are vitally important at this time when it is difficult if not impossible to envisage more than a very few atomic bombs being dropped on cities and industrial targets in Britain if war broke out in the near future.

It is to be hoped that the Government will consider producing a much shortened version of this publication for general circulation. The manual contains many technical inessentials which could be taken out for this purpose; the appendix about elementary atomic physics is really inadequate for the average person, and clearer and neater expositions of the elementary scientific facts are available elsewhere in books that are available in every public library.

A Noted Geologist

GEOLOGISTS in particular should be commemorating Abraham Gottlob Werner, born on September 25 two hundred years ago. Although so many of his views are now known to be untenable, science is indebted to him for his teaching and demonstration of a chronological succession of rocks. His work opened up a wider approach to geology.

Werner's choice of geology, after a period in his father's iron works, seems natural enough. From being a student in mining he developed his intense interest in mineralogy and hence geology. For forty years he taught his science, making the Freiberg school a centre in Europe and inspiring many other students who were to become eminent themselves. His special interests were mineralogy, lithology and classification of geological formations. Werner never travelled; his conclusions were drawn from the rocks of Saxony.

Above all, Werner goes into history's pages as leader of the 'Neptunists'. He postulated that all rocks were precipitates from a primeval ocean; firstly the granites, then the basalts and finally, as the ocean level became reduced and exposed rocks were weathered, came the sedimentary rocks. Opposed to these views were the 'Vulcanists' who rightly interpreted igneous rocks as the result of vulcanicity. For many years a great controversy raged between the two schools of thought. Werner's was a mistaken view, but the

controversy it aroused violently stimulated scientific inquiry in the youthful days of geological science.

"Impact of Science on Society"

THE literature on the social relations of science is already quite extensive and growing rapidly; it is, however, very scattered and some of it is by no means easy of access. That being so, a journal that provides a guide to the literature of this subject is to be welcomed. Unesco has produced the first number of *Impact*; its full title—*Impact of Science on Society*—is self-explanatory. The first number of this quarterly contains a useful reading list of relevant 'social relations' books; it has a dual character, being bibliographical as well as providing abstracts of current literature. The journal, which costs 1*s.* 6*d.* a copy, is to be obtained through H.M. Stationery Office; inquiries about subscriptions should go to *Impact*, Unesco, 19 Avenue Kleber, Paris 16

Have Atomic Explosives any Peaceful Uses?

THERE is little prospect of atomic explosives finding any peacetime use according to an article in the June *Bulletin of Atomic Scientists* by an expert of the Los Alamos Laboratory, Frederick Reines. He says it would take a huge number of bombs, perhaps hundreds or even thousands, to move any appreciable fraction of a mountain. By the same token, although an atomic bomb could be useful in breaking up a few small icebergs, it does not look promising as a tool for causing any important rearrangement of the Arctic ice. As for melting the polar icecap, if all the energy released by one bomb were so employed, it would melt much less ice than it could pulverize—i.e., it could melt a sphere approximately two hundred feet in diameter.

As to radioactive residues left behind by atomic explosives he states that any use in which the fission products are retained in a small region will result in a high and perhaps lethal level of activity for at least a period of months.

The article leads one naturally to the conclusion that the Russian story of atomic explosives being used in civil engineering projects is propagandist.

Radioactive Golf?

ATOMIC energy has invaded sport. Research workers of the Goodrich Chemical Corporation of America report the development of a radioactive golf ball. A minute amount of radioactive material is placed under the cover of the ball. The emission is too small to be dangerous to health but strong enough to be detected by a small Geiger counter. This, it is claimed, will solve the problem of the lost ball. A golf-club equipped with one or two Geiger counters could largely eliminate the heavy annual losses of golf balls by its members. It is estimated that at least half of the balls bought each year by American golfers are lost in the rough. On the other hand, Geiger counters are not expensive; one portable type is being advertised at 54 dollars.

New Vitamin Group Discovered

DISCOVERY of a new group of B-vitamins which promise to be of great value in combating sprue and nutritional and pernicious anemia was announced by Professor William Shive of the University of Texas at the American Chemical Society's 117th national meeting. The new vitamins have been named the *folinic acid group* and are directly related to folic acid, which they may replace in the treatment of anemia and sprue. No clinical investigations of the folinic acid group have been made as yet, Professor Shive emphasised, explaining that his conclusions as to the potential importance of the new vitamins were based primarily on microbiological tests. These tests indicate, however, that the folinic acid group is utilised more effectively than folic acid by most organisms—sometimes as much as 100 to 1000 times more effectively. One organism, in fact, was found unable to use folic acid at all, but it could use folinic acid, suggesting that the new vitamin group may be effective against some disease that cannot be treated with folic acid. Beef liver is particularly rich in folinic acid.

Colour Films on Pests

SHELL Film Unit have made ten colour films on the life histories of pests and the various stages of diseases: Codling Moth, Apple Aphis, White Fly, Leatherjacket, Flea Beetle, Cabbage Root Fly, Brown Rot, Winter Moth, Raspberry Beetle and Red Spider.

If the standard of photography in these last three films can be taken as typical of the rest then the Film Unit are to be congratulated. Not the least of the production difficulties in making films of this kind is encountered with the very powerful light necessary for colour cinephotomicrography. Some insects were fatally attracted by it, others were driven away. This difficulty was overcome by using an anaesthetic on the insects. This evaporated rapidly and the camera had to work fast in order to record the movements of the insects before it wore off altogether.

The films have been designed primarily for the agricultural and entomological student; they are in fact essays on 'pure' zoological subjects, but the producers envisage that they will appeal also to less academic audiences such as farmers, commercial growers and horticultural societies. Such audiences, however, will no doubt notice the omission of information dealing with the control of the pests and diseases. While it is commendable that the Shell Publicity Department have refrained from using these films solely as a means for advertising their own products, this omission detracts considerably from their practical value to large audiences.

16 mm. and 35 mm. copies (with sound) of these films are available. Further details can be obtained from Shell Chemicals Ltd., 112, Strand, W.C.2.

Sex Hormones in Crops

A RECENT article in *The Lancet* has focussed attention upon Australian and British research which has demonstrated the presence of oestrogens in pasture herbage. In 1941 sheep farmers in Western Australia were alarmingly confronted with severe decline in the fertility of their flocks. On some farms sheep-breeding had to be given up as unprofitable. Agricultural and veterinary research found that the trouble was nutritional rather than infectious. It was traced to the introduction of a new variety of subterranean clover; on those pastures where this variety had become the dominant species of herbage the loss of ewe fertility was the most severe. Grazing upon this apparently luxuriant clover produced abnormal teat and udder development in virgin female sheep and even in sterile male sheep. Lactation was induced in the former cases. Since similar effects could be produced by oestrogen treatment, it seemed clear that the clover contained either a potent oestrogen substance or some other substance which caused hormone imbalance in the animal. In 1948 it was reported that Australian scientists had extracted an oestrogenic substance from the clover. This substance is now being jointly investigated in Australia and England at the Courtauld Institute of Biochemistry.

The front of attack has been further widened by co-operation between the latter Institute and the National Institute for research in Dairying. Significant amounts of oestrogenic material in English pasture plants have been reported this year. This has strengthened the theory that the spring flush of milk so well known in this country is related to hormone supply from the spring grass.

Industrial Bacteria

BACTERIA are used in all kinds of industrial processes from the production of yoghourt to the manufacture of solvents. In order to provide industry and research laboratories with the cultures they need, a national collection of industrial bacteria was begun at the Chemical Research Laboratory, D.S.I.R., early this year.

Inquiries, requests for cultures, etc., should be addressed to the Director, Chemical Research Laboratory, Teddington, Middlesex.

Metallurgy at the Science Museum

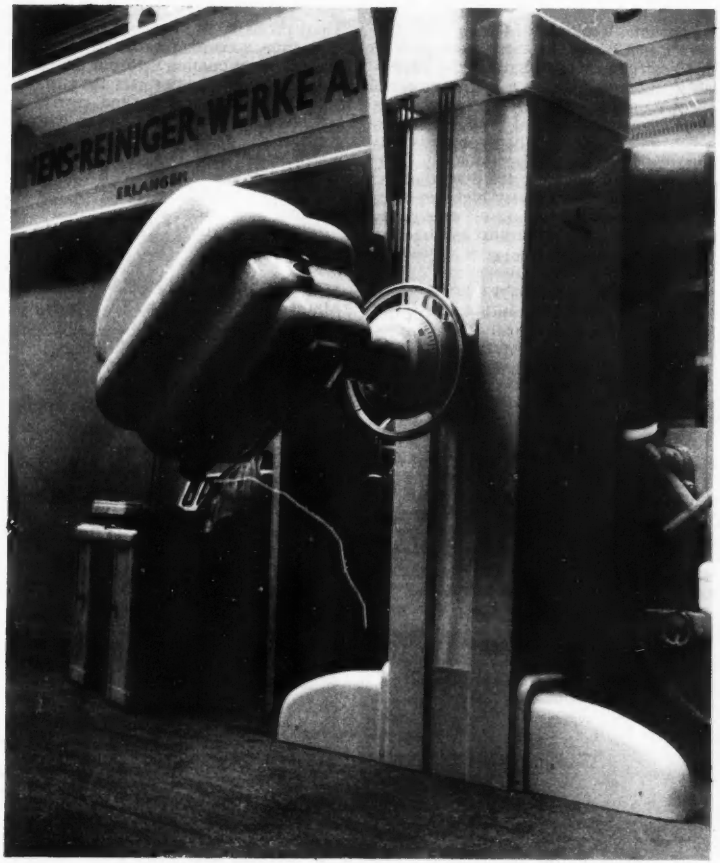
A SPECIAL exhibition entitled "Metals in the Service of Mankind" will be open at the Science Museum until September 30.

Inoculation and Infantile Paralysis

FIGURES of cases of infantile paralysis (poliomyelitis) among children immunised against diphtheria indicate that the immunisation increases the risk of a child developing poliomyelitis. The results of a statistical investigation by two scientists of the London School of Hygiene are published in the *British Medical Journal* (July 1, 1950, p. 1). The Ministry of Health is advising doctors to suspend immunisation schemes during epidemics of poliomyelitis.

A New Road Surfacing

A NEW attempt to improve British roads was started recently when a strip of 'Mealorub' surfacing was laid at Acre



Outstanding among new approaches at the International Radiology Congress in July were the first two commercial betatrons to be shown publicly. Each is designed for medical use, its electron beam being used like X-rays for cancer treatment. The Siemens instrument (top) *gives a 15 million volt beam; the Allis-Chalmers betatron* (below) *is a 26 million volt instrument.*

Lane, Lambeth. Although there is evidence to show that this composition outlasts any other type of road and is more skidproof, yet the only departure from normal practice is the addition of 5% of Mealorub to the aggregate mixer.

Mealorub was developed by the Proef Experimental Station at Buitenzorg in Java and consists of flocculated natural rubber latex. It wears well; thus several strips that were laid before the war and were subjected to heavy military traffic during the hostilities emerged after seven years with the quality of an average B-road, whereas the surface of non-rubber roads had gone completely.

Trials in America have also indicated the usefulness of Mealorub. Skid tendencies seem to be reduced.

At Acre Lane skid tests carried out by the Road Research Laboratory recently did not give any significant results. This was not unexpected because the granite chips used in the composition have not yet bedded down.

The June 1950 issue of *Rubber Developments* is devoted almost entirely to the subject of rubber in roads.

75 Years of Pump Manufacture

THREE-QUARTERS of a century of industrial progress was commemorated by the Pulsometer Engineering Company Ltd., of Reading on July 8, 1950.

In 1875, in a small works in Battersea, with thirty employees, the late John Eliot Hodgkin began to manufacture The Pulsometer—a new type of Steam Pump destined to make pumping history. This small Battersea concern became The Pulsometer Engineering Company Ltd., now at Reading.

Pulsometer today makes centrifugal, turbine, rotary and vacuum pumps, comprising some seven hundred different types and sizes for all duties.

'Pulsometer' vacuum pumps are of particular interest. Fifty years ago no practical mechanical high vacuum pump existed, though certain low vacuum mercury types were in use in laboratories. Pulsometer experiments developed the 'Geryk' air pump which gave results far beyond anything hitherto attained and which has since made X-ray tubes, wireless valves and incandescent lamps, workable propositions. 'Geryk' high vacuum pumps today work in almost every lamp and radio factory in Britain, are being used in delicate surgical operations, for blood transfusions, and in innumerable laboratories and factories.

Earth Growing Warmer says Prof. Urey

RADIOACTIVITY was largely responsible for the development of the earth as we know it, according to Prof. Harold C.

Urey, in a lecture to the Fifth Annual Southwest Regional Meeting of the American Chemical Society, he suggested that heat generated by radioactive materials in the heart of an ocean-covered earth brought about vast structural changes which gave us the great land masses on which we live today. The hypothesis outlined by Dr. Urey differs radically from the view, widely held in the past, that the earth was formed at a very high temperature and has been cooling off ever since. On the contrary, according to the new theory, the earth has grown warmer since it 'accumulated' many millions of years ago from a huge dust cloud which the sun had acquired during its travels through space.

At the start, Dr. Urey said, the earth probably consisted of a low-density core followed by a layer of a mixture of iron and stone, and on the surface a very thin layer of rock. Covering the whole was a layer of water. During the first stage of the earth's history, radioactive uranium, thorium, and potassium in the stony regions raised its temperature until the iron layer melted. Then the iron dropped to the centre of the globe, forming a heavy dense core, which displaced the lighter materials originally there and floated them up to the surface. It was thus that the continental land masses and the deep Pacific basin were formed, he explained. There probably was only a single continent for a time, according to the theory, but as material kept coming up from the earth's core and spreading out near the surface it broke this continent up and carried the sections apart. This idea ties in with the continental drift theory, advocates of which have noted that the eastern coast of the New World looks as if it had been split from the western coast of the Old World.

Personal

MR. R. E. BURNETT, formerly head of the Mathematic, Physics, and Electrical Engineering side of the Technical and Scientific Register of the Ministry of Labour, has been appointed Manager of Education Department and Principal of the Marconi College at Chelmsford, Essex.

Weed-killer for Couch Grass

A WEED-KILLER effective against couch grass has long been needed. It is reported from Australia that this weed can be controlled with ammonium trichloroacetate; at 100–200 lb. to the acre this chemical gives excellent results, and the couch grass shows no sign of growing again even six months after treatment.

Sir Henry Tizard has relinquished some of his duties as Scientific Adviser to the Defence Minister to Sir F. Brundrett.

Sir Frederick Brundrett becomes deputy to Sir Henry Tizard, leaving the Admiralty where he directed the R.N. Scientific Service.

Prof. P. B. Moon, Poynting Professor of Physics at Birmingham, successor to Prof. Oliphant who is now directing physics research at the Australian National University, Canberra.

Gordon Dean, now Chairman of the U.S. Atomic Energy Commission. David Lilienthal vacated the office in February this year.

New Harwell Isotope Separator

A SECOND Electromagnetic Isotope Separation Plant has been completed at the Atomic Energy Research Establishment at Harwell and the collection of separated or enriched isotopes has started. A small electromagnetic separator has been running at Harwell for two years and has been supplying samples of isotopes of light elements for nuclear physics work. The new plant is capable of separating for experimental work grams of the isotopes of the heavy elements, including uranium, at a high degree of enrichment, and the first separations were carried out in May.

While the large plant is expected to be fully occupied on work for the Establishment for some time to come, milligram samples of the lighter elements made by the smaller plant will be made available for export, as well as for use in Britain, as supplies permit.

African Vines and Cortisone

AN expedition organised by the Medical Research Council and led by Dr. R. K. Callow has spent six months in Nigeria collecting plant material for cortisone research. Several months ago it was reported that seeds of the African vine *Strophanthus sarmentosus* could be used to increase supplies of cortisone (see DISCOVERY, December 1949, p. 368 and 371). Dr. Callow's expedition has brought back a hundredweight of these seeds, and also a large quantity of seeds of the related species, *S. hispidus*. These are now being analysed chemically. The vines are widespread in Nigeria; supplies of the seeds would be more abundant in Africa today were it not for the fact that in the past the authorities tried to stop the cultivation of the vines from which the natives obtain a poisonous extract used to tip their arrows.

Wanted: A Perfect Optical Cement

MODERN optical instruments are usually equipped with a considerable number of lenses, in order that the images presented may be as nearly perfect as possible. It follows that the number of air-glass surfaces must of necessity be fairly large, but every time light passes through a glass surface from the air a certain proportion of it is lost. One of the most effective solutions of this problem is to cement some of the lenses together, which has the further advantage of preventing surfaces from being contaminated by dust and dirt.

An optical cement must be chemically and physically stable, it must be optically clear and free from colour, its refractive index must lie within fairly narrow limits, and it must be unaffected by light. The perfect cement must also be capable of withstanding extremes of temperature, and should be resistant to moisture and unattacked by fungi. At present there is no known cement which fulfils all these requirements.

The traditional optical cement is Canada balsam. But it is far from perfect.

Among the organisations searching for the ideal cement is the British Scientific Instrument Research Association.

The Bookshelf

Atomic Attack—Can Britain be defended? (Association of Scientific Workers, London, 1950, pp. 22, 1*s*.)

THIS latest publication of the A.Sc.W., to which Professor Blackett contributes a foreword, is an attempt to sketch out once more, this time in miniature, the military and political consequences of atomic energy as the A.Sc.W. sees them. This pamphlet is rather curiously arranged, for the appendix on the hydrogen bomb would have made a neat introduction, while Professor Blackett's foreword would have served better as an inference drawn from the technical facts which form the main body of the pamphlet.

The broad and now familiar thesis can be summed up very briefly. Atomic weapons are not likely to be decisive if used against the United States or Russia, but they would be decisive if used against Britain. Adequate defence of Britain against atomic attack is quite impracticable, if only on economic grounds. Professor Blackett admits that he is not very clear as to what positive steps should be taken to minimise the likelihood of atomic attacks on Britain in case of a war between the two giants, but he clearly sees the major blunder to be avoided at any cost: "This is to rely for our military policy on the use of atomic bombs (whether of British or American manufacture is no matter) from British air bases, without preparing adequate defence measures against enemy attacks on this country. Since such a defence plan is economically impossible, any such military policy would be unsound." The conclusion is irresistible that "the United Kingdom must have a policy of its own"—a convenient euphemism for saying that it should sever its military and strategic links with the United States and presumably content itself with sitting on the fence.

The whole argument is as simple as it is false in its premises and illogical in its conclusion. For the peculiar vulnerability of Britain to atomic attack as compared with the relative safety of the United States and the Soviet Union is an illusion rather than a strategic reality. The whole meaning of weapons of saturation of transoceanic range is that they tend to level out the inequalities between nations, especially the inequalities of geography. To knock out a country of the size of Russia, it would not be necessary to blast every square mile of her territory; the wiping out of the vital centres would be sufficient, and the number of vital centres in Russia are not much greater than that in Britain. The whole idea that atom bombs place Britain in a special predicament in comparison with continental giants is a hard-dying conception inherited from the days of conventional weapons.

But even if this premise were perfectly sound, the conclusion which Professor Blackett draws from it would remain false. Presumably, he, like the rest of us, wants to avoid another world war. In present circumstances, the only way of achieving this is to confront the would-be aggressor with the certainty that he has nothing to gain and everything to lose by starting the shooting. As long as the would-be aggressor is confronted with an alliance embracing the United States, the British Commonwealth and a revived Western Europe he can be in little doubt about his chances of success. But should Britain —as Professor Blackett advocates—break away from the alliance, a large part of the Commonwealth and probably all of Western Europe would follow her example. Nothing could be more encouraging for the would-be aggressor to take a chance and precipitate a third world war.

The path of neutrality, though it may bring advantages to small nations like Sweden or Switzerland, is not the one to be trodden by great nations with world-wide interests. As Machiavelli pointed out, those whom irresolution leads on to the path of neutrality are generally ruined, and thus it is that he who is not your friend will demand your neutrality, whilst he who is your friend will entreat you to declare yourself with arms. "Because he who conquers does not want doubtful friends who will not aid him in the time of trial; and he who loses will not harbour you because you did not willingly, sword in hand, court his fate."

E. M. FRIEDWALD.

The Nature of the Universe. By Fred Hoyle. (Basil Blackwell, Oxford, pp. 121 with 6 photographs, 5*s*.)

THIS little book is based on a recent series of broadcast talks given by the author, one of the most prolific of present day writers on mathematical astronomy and astrophysics. It avoids the usual defect of republished broadcast talks—the thinness of exposition essential to the lucid spoken word; its style is forcible and entertaining. I read the book with interest—at a single sitting—even after a previous reading of the original talks. I am convinced that the book will sell like hot cakes. I am also convinced that, quite shortly, Mr. Hoyle will begin to regret having published it.

There are two approaches open to the writer expounding a subject in which he himself is working. He can attempt a survey of the whole of the work done in the field (including references to his own efforts), being careful to say which parts are agreed, and concerning which there is controversy. This is a safe but possibly slightly dull way of going on. Or he can write what is, in effect, a monograph, dealing mainly with his own work, or with the school or group of workers to which he belongs. This is more exciting; the writer has the courage to bet on himself, but he inevitably makes himself the target of criticism on an entirely personal basis. This may be regrettable, but the writer cannot say that he didn't ask for what he may get. Not only that, he ought, as a responsible person to make sure that when he is writing in a personal vein, his statements are not liable to be taken as expressions of what is generally believed to be true by an audience not in a position to criticise for itself.

This, it seems to me, is the position in which Mr. Hoyle has landed himself. A large part of the book is concerned with a description of the recent work of himself and his own circle at Cambridge. Much of this work may be very admirable but it cannot be maintained for one moment that it is representative of modern astrophysics, or that a majority of astronomers believe that this work, full of brilliant mathematics though it is, truly represents the state of the universe.

If, as the publisher's blurb says, Mr. Hoyle's book is supposed to be in the tradition of Jeans and Eddington, he might have taken a tip from *The Universe Around Us* where Jeans has much to say about the hypothesis of liquid stars, a pet subject of *his*. If this hypothesis is not as dead as the dodo, not even the most optimistic of astronomers can see much sign of life in it at the moment. Most of these mathematical theories, so satisfying to their creators, are so relatively short lived that common prudence would seem to suggest the unwisdom of making too much of a song and dance about any particular one. To give an example, according to Mr. Hoyle, stellar accretion from inter-stellar material is the answer to many problems, This may well be: the idea is an excellent physical one: but to suggest, as I understand Mr. Hoyle to do on p. 57, that this is the accepted mechanism of the formation of the solar corona, without reference to the work by literally dozens of other people, seems to me to be most unwise. This is typical: throughout the latter part of the book, statements are made that we 'know' this or that, to which most astronomers will reply "We don't know anything of the kind." Mr. Hoyle is extremely definite about highly controversial subjects, such as the origin of the solar system, stellar evolution, the origin of galaxies and so forth: in fact his group is only one of many with ideas on these subjects, and he might have been warned by the fact that on at least one of these topics, the ideas of the group itself have undergone a complete *volte face*. I don't wish to labour the point: the critic who wishes to be honest is placed in a difficult position when he feels that someone for whom he has a great respect pursues an unwise course. It would have been better not to give talks in this style so permanent a form as a printed book.

D. S. EVANS.

The Planet Mars. By Gérard de Vaucouleurs. (Faber and Faber, London, 1950, pp. 87 with 5 pages of illustrations, 10*s*. 6*d*.)

THIS translation by Patrick A. Moore of the French version of M. de Vaucouleurs' book is as nice an example of book production as one has seen for a long time. The printing, paper and half tones are all very good. The price seems somewhat high, but one gets quality for one's money.

It is not quite clear for whom the book is intended: the discerning amateur who wants a handy reference book of Martian information will find it most valuable; but it is written in such lucid fashion that

the completest of astronomical tyros may take pleasure in it. What is perhaps surprising is that so little should be known about Mars even after several centuries of telescopic observations.

D. S. EVANS.

Volcanoes New and Old. By S. N. Coleman. (Museum Press Limited, London 1950, pp. 212, 97 photographs and 2 maps, 16*s.*)

THIS is a story book, as the author forewarns us, about volcanoes, many actively living, some dying and others deceased. It begins in Mexico with Dionisio Polido ploughing his cornfield and witnessing the birth of Paricutin, the world's most recent and fated volcano.

Paricutin grew with amazing rapidity, a gigantic pile of black cinders in the once fertile valley, where red hot lava flows destroyed farms and villages in their path. No one, after reading the first chapter could put this book aside unread. The causes of such paroxysmal outbursts, the nature of the rocks brought up from the earth's interior and the various kinds of volcanoes are all clearly outlined.

The greater part of the book, however, is descriptive, and magnificently illustrated by photographs. It contains a wealth of easily assimilated information, not only about the major eruptions of well-known volcanoes, but historical accounts of the people who lived and died in these volcanic areas. No reference is made to the really old volcanoes of the British Isles; perhaps they are too ancient.

This book will appeal to the general reader, the student and to those who have been fortunate enough to travel in the Mediterranean and the Pacific. It is well produced, the photographs are all excellent, but the world map showing the distribution of major volcanoes unfortunately omits those parts of the Pacific and North America between 120 and 145 degrees west.

F. A. HENSON.

Short-Wave Radio and the Ionosphere. By T. W. Bennington. (London, Illiffe, 2nd edition (previously published under the title *Radio Waves and the Ionosphere*), pp. 138 with 57 illustrations and 3 plates, 10*s.* 6*d.*)

IN this book, the author provides an account of the part played by the ionosphere in long-distance radio communication.

For the reader who has not made a detailed study of ionosphere propagation the physical processes involved have been explained as adequately as is permissible in a descriptive manner without the use of detailed mathematical expressions. On the other hand those who are familiar with the necessary fundamental theory will find a wealth of practical information and numerous graphs illustrating ionospheric phenomena. These are well related to others dealing with the consequent communications conditions, and the book should have a wide appeal.

The subject is developed in logical sequence. Following an introduction to the fundamentals of radio wave propagation, the formation and structure of the ionosphere are explained. Then the author deals with the effects of the ionosphere on radio waves and the measurement of its characteristics in this respect. The variation in ionospheric properties and its effect on short-wave communication is then explained, together with the resultant necessity for the choice of optimum transmission frequencies and of angle of elevation of the transmitted radiation. These considerations introduce the necessity for forecasting ionosphere conditions, and the derivation in advance of associated transmission data for reliable long-distance communication. In addition, related problems in amateur practice are also considered. In dealing with these points, particularly those latterly mentioned, more space is devoted in the second edition, and the many additional illustrations should be found to be valuable for reference.

The title might suggest that the text explains the technique necessary in order to fulfil the required transmission conditions. In fact, little is said about this. The aim of the book, as stated in the preface, is to present information about the role of the ionosphere in long-distance short-wave communication.

A. A. ROWLANDS.

Pocket Encyclopedia of Atomic Energy. By Frank Gaynor. (New York, Philosophical Library, 1950, pp. 204, $7.50)

RAPIDLY rising specialisation has brought with it a widening vocabulary of technical terms and at the same time an increasing inter-relationship of the many branches of science. What modern biologist, for example, would be happy without some acquaintance with radio isotopes? Consequently everyone working in science needs all the handy reference encyclopedias he can get.

This book is one of them. It has over 2000 entries, including some biographical material. It is notable for a comprehensive list of isotopes and for charts of neutron excesses in the elements, facts that usually necessitate considerable searching in original papers. It suffers, of course, from being somewhat out of date by the time it is published—Sir John Cockcroft is still described as a professor at Cambridge. It has also some weaknesses —I find the definition of 'chroma' as "the purity of one wavelength free from all others" quite incomprehensible. But such defects are inevitable in a first issue; there is no such thing as a perfect reference book on a living and developing subject. So this book, the first of its kind in the English language, is a necessary addition to every modern library. C. L. BOLTZ.

Practical Physics. By Sir Cyril Ashford. (London, Cambridge University Press, 1950, pp. 173, 10*s.* 6*d.*)

WITH the approval and encouragement of the Local Examinations Syndicate, Sir Cyril Ashford has used the practical physics exercises set in the Cambridge Higher Certificate Examination between 1932 and 1947 as the basis of a teaching textbook. The experiments in their present form have benefited by the experience which the author gained as an examiner from the candidates' results, and from the comments of their teachers and moderating examiners. Because of these origins the book is not a comprehensive course in practical physics but, being influenced by the balance of the examination, is biassed in a manner which will be found most useful by students preparing for practical examinations in physics.

Following a very thorough note on the reduction of observations, the book is divided into Part I Mechanics, Part II Light, and Part III Heat and Electricity: fifty experiments in all. One does not usually find in similar textbooks a number of the experiments described here, such as those on fluid friction, oblique incidence on a lens, and variation of viscosity with temperature.

Since they were suitable for practical examinations, all the experiments here will require no apparatus which does not exist in the laboratories where the book is likely to be used. The author goes fully and deeply into each problem, and adds a theoretical note to each which, he emphasises, is desirable but not essential for the student. While this full theory will extend the knowledge of the strongest Higher Certificate candidates and many first-year undergraduates, the practical instructions and hints are stated in a detailed manner which will be readily followed by all.

The whole book will be of great value to students and teachers at the Higher Certificate and University entrance stage. I should have been interested to have seen, perhaps as an appendix, the actual wording of the examination questions upon which the experiments here were based. It would be most useful if examining bodies in other scientific subjects would encourage their examiners to write similar books explaining to candidates what they had in mind when setting examination questions. S. J. B.

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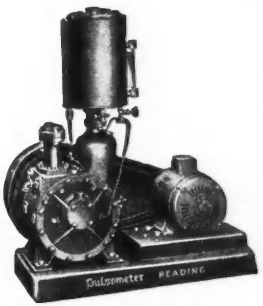

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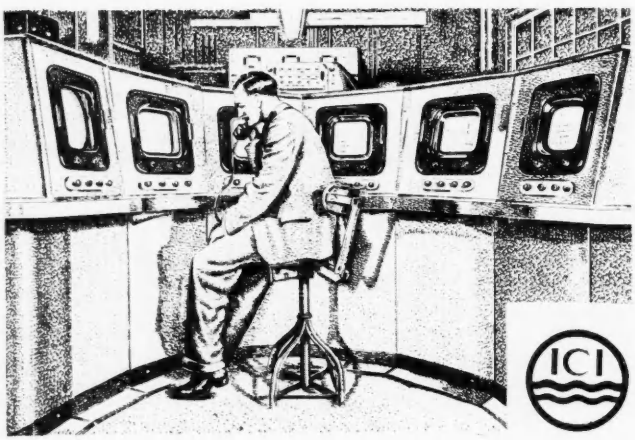
Polythene was essential for the development of another great achievement of British research — radar. The illustration shows the radar installation at the port of Liverpool. Polythene, or polymerised ethylene, is a tough yet flexible plastic with remarkable qualities as an electrical insulator. The name is generic for a range of solid polymers of ethylene, a gas derived from alcohol or petroleum. Ethylene will not polymerise easily, that is, the molecules will not join together in long chains, but in 1933, I.C.I. chemists found that under extreme pressure they could be made to do so. This was in itself a major scientific achievement, but equal skill and more patience were needed to develop polythene to the stage of commercial production. The pressures used — sometimes exceeding 10 tons per square inch — had never been employed before in chemical processes, and at the beginning there were many explosions, one of which almost wrecked the laboratory. The process was finally mastered in 1936, and the first plant manufacturing polythene came into production on 1st September, 1939, the day the Germans invaded Poland. Never was a product more timely in its arrival. Today it is finding many uses, the most important being the improvement of submarine telephone and telegraph cables.